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ORIGINAL ARTICLES.

Notes on British Dinosaurs. Part VI: Acanthopholis.[1]

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(PLATES VII AND VIII.)

FIFTY years ago, when Professor Seeley gave his masterly description of the Dinosaurs of the Cambridge Greensand,[2] so little was known of these animals that it was naturally impossible to co-ordinate the different remains and to fix their systematic position. Up to 1902 scarcely any attempt was made to review Professor Seeley's conclusions. In that year I tried myself, in a paper,[3] to determine their systematic position, but I find I was mistaken in some points. In 1917 Mr. Bajazid Elmas discovered at Szentpéterfalva some remains of *Struthiosaurus* that throw much fresh light on the position of this genus, and thus also on the allied genus *Acanthopholis*. Owing to the war the utilization of these discoveries had to be postponed, but now an attempt can again be made to group the Dinosaurs of the Cambridge Greensand.

We find three types of jaws. One resembles the jaw of *Struthiosaurus* found in the Gosau of Lower Austria. The second type is indicated by the tapering and elongated root of a tooth showing the same feebly polygonal cross-section as characterizes the teeth of certain Camptosaurians, for example *Rhabdodon*. The third is represented by the thickened proximal end of a right maxillary, of which only the outer half is preserved. This fragment shows on the interior side eight narrow and very deep alveoli such as are to be met with only in the Trachodontidae. A fragment of a similar dentary is in the Museum of Practical Geology in London. A tooth has been described as *Trachodon cantabrigiensis*.[4]

The Dinosaur claws of the Cambridge Greensand indicate four rather different types. One of the claws (Pl. VII, Fig. 1) is rather pointed, laterally compressed, and moderately curved, but without the lateral furrows which characterize the claws of the Theropoda; it belongs therefore to a Sauropod. The second type is likewise elongate, but flattened from above downwards (Fig. 2) and has a rounded anterior margin; it agrees with the claws of *Iguanodon* and *Camptosaurus*. The third type is somewhat similar, but much

[1] Parts I–V, Geol. Mag., 1902–12.
[2] *Q.J.G.S.*, 1871.
[3] *Sitzungsber. Akad. Wiss. Wien, Math.-naturw. Cl.* 1902.
[4] Lydekker, *Cat. Foss. Rept., Brit. Mus.*, 1889.

shorter and less compressed (Fig. 3); it shows, therefore, affinities with *Trachodon* or *Stegosaurus*. The fourth type is thick, pointed, and triangular in outline (Fig. 4); it thus represents an unknown type.

Three of the four types of Dinosaurs indicated by the claws can also be recognized by studying the different caudal vertebrae. One for which the name *Anoplosaurus* may be retained is clearly Camptosaurian; the second belongs to a Sauropod named by Seeley *Macrurosaurus*; the third may be well determined as belonging, together with the *Struthiosaurus*-like jaw, to the genus *Acanthopholis*. For the fourth type of vertebra that may be perhaps united with the *Trachodon*-like maxillary and claw, Seeley proposed the name *Eucercosaurus*. In the tail of this genus the vertebrae show a strongly compressed centrum.

Only after having established in this preliminary manner the types of Dinosaurs that are certainly present in the Cambridge Greensand the odd bones can be sorted. We find Acanthopholid, Camptosaurid and Sauropodous bones. How little Seeley's grouping of these bones agrees with the grouping here proposed may be gathered from the following remarks. The dentary, the scapulae and coracoids, named *Anoplosaurus curtonotus*, are of Acanthopholid type, and therefore do not belong to this animal, but with the centra of one cervical and two caudal vertabrae named *Anoplosaurus major*, may be referred to a small individual of *Acanthopholis*, while the other remains undoubtedly belong to *Anoplosaurus*. On the other hand, the proximal caudals described by Seeley as *Acanthopholis* are of Camptosaurian outline, and must therefore be removed to *Anoplosaurus*. The "*Acanthopholis platypus*" metatarsals are in reality phalanges of *Macrurosaurus*, etc. On this account a renewed description, however short, of some of the Greensand Dinosaurs at least seems desirable.

In this paper it is proposed to deal only with those remains that belong evidently to *Acanthopholis*, so that all material not mentioned here is presumed to belong to other types. In another paper *Anoplosaurus* will be described; *Eucercosaurus* will be dealt with later. Seeley's *Syngonosaurus* is perhaps not a separate genus, for it certainly includes remains of *Anoplosaurus*, while the rest may belong to *Eucercosaurus*.

(1) *Skull.*—Of the skull of *Acanthopholis* only the basis cranii and the dentary bone are known. The former was well described by Seeley in 1882, the latter in 1871. In the base of the skull attention is drawn to the lateral and backward extension of the brain-case above the condyle, bringing the condyle right under the brain and indicating a head at right angles to the neck. The lack of tubera basioccipitalia and the same shape of sella turcica as in *Struthiosaurus* must also be mentioned. All the bones of *Acanthopholis* are thicker than those of *Struthiosaurus*.

In the dentary must be mentioned the sigmoid curve of

the alveolar margin, which is a quite characteristic feature of *Stegosaurus*, *Struthiosaurus*, and *Acanthopholis*, but this margin is not brought out in Professor Seeley's drawing, which represents the exterior aspect of the bone. The development of the alveoli and their restriction to the margin of the jaw are exactly as in *Struthiosaurus* and *Stegosaurus*, and differ from that of the Ornithopodidae. Finally, it may be noticed that the absence of a ridge on the upper and outer side of the dentary indicates the lack of a coronoid process. A coronoid process is wanting in *Stegosaurus*, *Sarcolestes*, *Struthiosaurus*, *Ankylosaurus*, and *Panoplosaurus*, but not in *Scelidosaurus*.

(2) *Vertebrae.*—The vertebrae of the different specimens of *Acanthopholis* vary greatly in size, for they belong to different individuals. Specific names might be given to some, but, as neither the sexual differences nor those produced by age are known, the creation of new species seems premature. The best preserved cervical vertebra, belonging to an individual of medium size (Figs. 5–7), has a rounded centrum with a somewhat flattened base, expanding at both ends. The articulation-surfaces are flat, and their outline is subtriangular with very rounded corners, the point of the triangle being directed downwards (Fig. 6).

The articulating facet for the capitulum (Fig. 7) of the cervical rib is a well-marked, smooth, round concavity, placed on a strong rugose peduncle rising halfway up on the centrum somewhat behind its anterior margin. This peduncle projects very markedly backward (Fig. 5) much as in *Omosaurus*. Between the sides of the vertebrae and the articulating surfaces no sharp limit can be drawn. On both known cervicals of *Acanthopholis* hypophysial bosses are missing, as in *Scelidosaurus*. In some of the dorsals of *Acanthopholis* the vertical diameter of the well-rounded articulating surface is greater. These high elliptical vertebrae seem to be lumbars. The centra of the vertebrae show a blunt keel on the ventral surface (Figs. 8, 10) straightening thus the basal concave outline of the centrum from end to end, and the transverse diameter of the upper half of the centrum gradually decreases; thus on these vertebrae, halfway up the centrum, a very blunt and longitudinal lateral swelling appears on each side (Fig. 9).

Unfortunately, until now nothing has been known about the sacral and proximal caudal vertebrae of *Acanthopholis*. The middle and posterior caudals are quite characteristic. The cross-section of these is always polygonal, eight longitudinal ridges being present on each of the middle ones, six on those situated further back (Fig. 12). The ridge corresponding to the costoids of the proximal caudals is in every vertebra the strongest; then follow two ridges that are situated in *Polacanthus* under the neurocentral suture, but rise on to the arch in the later caudals. After this pair of ridges, according to size, two further ridges must be mentioned, which run along the base of the converging flanks of the centrum and are

very near to each other. Finally, on the middle caudals there are still two longitudinal swellings situated under the ridges that correspond to the costoids.

In the middle of the tail the vertebrae are well defined by a deep longitudinal groove between the basal ridges (Fig. 11). This feature disappears further fore and aft. All the middle and posterior caudals are biconcave, and generally only the posterior facet for the chevron bones is well developed.

In the very latest caudals, where the neural arch is only a feeble roof for the medulla, the haemapophyses are short and broad (Fig. 14): they resemble to a certain degree those of *Hylaeosaurus* and co-ossify along the principal haemapophysial facet with the centrum, to which they are most strongly attached. This has been observed also in *Struthiosaurus*. The articulating facet in the second half of the tail of *Acanthopholis* is first nearly circular in conformity with the polygonal cross-section of the centrum; later, when the lateral swellings vanish, it is ovoid in outline with the sharper curve below; still further back, as the depth of the centrum decreases, it attains a somewhat broad hexagonal shape; and at the end it is broader than deep, and nearly elliptic transversely.

(3) *Ribs.*—The single rib that can be referred to *Acanthopholis* is a cervical very similar to that of *Struthiosaurus*. Since it has not yet been figured, a photograph is given in Fig. 15.

The rib is flat, its surface is somewhat rough, the capitulum is strong and well marked, the tuberculum is weaker but nevertheless clearly visible, forming a small head with nearly circular outline. The lateral flange which occurs on the cervical ribs of Sauropoda or Theropoda is not visible. The evenly flattened-out laminar shape distinguishes this rib at once from that of all those Dinosaurs in which the cross-section of each part of a cervical rib is circular or elliptical.

(4) *Shoulder girdle.*—Although the shoulder girdle of *Acanthopholis* has hitherto only been known by fragments, nevertheless one of them, the proximal end of a scapula, is of great importance. It has been already figured by Seeley under the name of *Anoplosaurus*, so no drawing of this bone need be given again. It resembles a hitherto undescribed scapula of *Struthiosaurus*. On comparing the two bones, it becomes evident at once that they are built on the same lines, and if we compare this type with the figures given for *Camptosaurus*, *Stegosaurus*, or a Ceratopsidian, the great difference is apparent. Both in *Struthiosaurus* and in *Acanthopholis* the most characteristic feature is the projection on the blade. It was called acromion by Seeley, and I think this name can be retained, although this prominence is not homologous with, but only analogous to, the acromion of Mammals.

The importance of this particular scapula lies in the fact that it proves beyond all doubt that some remains named *Anoplosaurus curtonotus* do not belong to an Ornithopodid Dinosaur, while other

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parts, such as the fragment of humerus and the claws of *Anoplosaurus*, indicate the contrary. From the merely morphological point of view, the piece is too badly preserved to be of great value.

The coracoid, which Seeley likewise described as *Anoplosaurus*, is characterized by the position of its foramen, which is entirely on the coracoid; on the outer side of the bone, however, on account of its oblique course, it touches the inner scapular surface, producing a notch on the scapular margin by the scapulo-coracoidal suture. This piece is also too much broken to be of special value.

(5) *Limb bones.*—Two fragments of limb bones have been described as *Anoplosaurus*, but may be supposed to belong to *Acanthopholis*. One is the proximal end of a femur, the other a piece of the distal end of the same bone. Unfortunately, both pieces are in so bad a state of preservation that the question cannot be settled.

The fragments of humeri described under the name of *Anoplosaurus* are rather referable to a Camptosaurian.

The phalanges of *Acanthopholis*, associated with the claw dealt with above and shown in Pl. VIII, Fig. 1, indicate a foot with three well-developed and separate toes, and a first toe reduced in length. It seems as if the middle toe was the strongest.

The three principal metapodials are moderately elongated, not so much so as in *Scelidosaurus*, but more than in *Stegosaurus*. They suggest those of *Polacanthus*. Their ends are moderately expanded, and they show that they were not applied so closely against each other as in the Ornithopodidae. Their inferior palmar surfaces are flattened, but the distal articular surfaces are directed as much upwards as forwards and show that normally the phalanges formed an obtuse angle with the metapodial. Thus the metapodials were normally carried in a semi-erect position, and therefore the foot of *Acanthopholis*, to which these metapodials belong, was evidently digitigrade. The metapodial of the first toe is quite as thick as the rest, and seems thus, on account of the shortening, a very stout and somewhat twisted bone. It is more shortened than in *Scelidosaurus*. All the phalanges are broader than long, their length decreasing forwards. They are never so short as in the Ornithopoda, and always more robust. They show no marked lateral grooves for strong ligamentous union. Their flexibility was reduced.

Since a short but characteristic description of the one claw known was given above, it is sufficient to mention here that the triangular claw is broadest at its base, and thick but very little curved. The sides diverge towards the palmar surface, so that at its proximal end it is nearly semi-lunar in section. Its palmar surface is somewhat concave. To a certain degree it suggests the claw figured by Marsh as belonging to *Stegosaurus*, and the fourth claw of *Scelidosaurus*.

(6) *Dermal armour.*—The dermal armour of *Acanthopholis* consists, so far as known at present, of some asymmetrical spines

and several symmetrical and asymmetrical scutes. All the scutes bear a longitudinal roof-like crest, rising towards one end. Since this crest extends generally further forwards than the base of the plate, it seems to be overhanging when viewed from the side. The outline of the scutes is irregularly subcircular or oval; they have, however, always a projection at the end where the longitudinal crest attains its culmination. This I presume to be the back end. Sometimes, especially in the longish plates, a sharp angle can be seen also at the other end. The inferior surface of each of the bones is flat round the margin, but hollowed out under the crest, the hollowing out forming consequently a longitudinal groove. This groove is not so deep as the crest is high, so the bone is thickest under the crest.

These dermal scutes of *Acanthopholis* resemble most the posterior caudal dermal bones of *Struthiosaurus*, although the latter are decidedly thinner. They resemble also to a very great extent the hitherto undescribed bones mentioned by Déperet as "*Cratacomus*" and *Hoplitosaurus*. The spines have been well described by Huxley. Their constriction above the base is unique among the Thyreophora.

Since symmetrical and asymmetrical dermal scutes are present, they were evidently arranged at least in three rows; the highest point of each scute was doubtless directed backwards as in *Polacanthus*. Probably the spines were confined to the scapular region as in this genus. It is sufficient to give illustrations of one spine (Fig. 16) and two of the plates (Pl. VIII, Figs. 3, 4).

(7) *Systematic position.*—The systematic position of *Acanthopholis* is indicated by the structure of the skull, the great development of the acromion on the scapula, the shape of the dorsal vertebrae, and and presence and character of the dermal armour.

The dermal armour and vertebrae at once bring *Acanthopholis* within the Thyreophora, the structure of the skull places it near to *Struthiosaurus*, and consequently near to *Stegoceras*, and separates it from *Ankylosaurus*, from *Scelidosaurus*, from *Stegosaurus*, and from the Ceratopsidae. Lastly, the scapula shows that there is a great systematic resemblance between *Acanthopholis*, *Hoplitosaurus*, *Hylaeosaurus*, and *Struthiosaurus*. Of the dermal armour of *Acanthopholis* too little is preserved to give definite evidence of its nature, but we may safely presume that it was constructed on the same lines as the dermal armour in *Hoplitosaurus*, *Polacanthus*, *Struthiosaurus*, and *Hylaeosaurus*, i.e. with spines on the shoulders and rows of low-crested plates on the end of the tail.

As already pointed out twenty years ago, *Acanthopholis*, *Struthiosaurus*, *Polacanthus*, *Hoplitosaurus*, *Stegoceras*, and *Hylaeosaurus* form a well-defined natural group, to be called Acanthopholididae. This group is identical with Lambe's Palisauridae established in 1921. From the Scelidosauridae and the Stegosauridae, which are closely related to each other, the Acantho-

pholididae differ by the structure of the base of the skull; from the Ankylosauridae they may be very well distinguished by the posterior and superior part of the skull. The Nodosauridae of N. America are perhaps to a certain extent allied to our group, but this has yet to be proved.

If the Thyreophora are considered as a super-family equivalent to the Ornithopodidae, the Acanthopholidae are a family within this super-family, this family again comprising the Acanthopholinae, Ankylosaurinae, and Nodosaurinae as separate sub-families. According to this classification, other families of the Thyreophora are the Stegosauridae and Ceratopsidae. Among the Stegosaurians of Europe and America the Scelidosaurinae, Stegosaurinae, and Kentrurosaurinae seem each to be a sub-family. In the family Ceratopsidae, which is not known in Europe, one phylum can evidently be distinguished with a strong nasal, and one with two strong preorbital horns; each phylum seems again to be a sub-family. Thus, on account of the discoveries made during the war, my classification of 1915 must be somewhat altered.

EXPLANATION OF PLATES VII AND VIII.

FIG. PLATE VII.

1.—Claw of Sauropodous Dinosaur (*Macrurosaurus* ?).
2.—Claw of Camptosaurian Dinosaur (*Anoplosaurus*).
3.—Claw of Trachodontid Dinosaur (*Trachodon cantabrigiensis* ?).
4.—Claw of *Acanthopholis*.
5.—Cervical Vertebra of *Acanthopholis* from below.
6.— ,, ,, ,, from front.
7.— ,, ,, ,, from the side.
8–9.—Dorsal ,, ,, below and from the side.
10.—Another Dorsal Vertebra of *Acanthopholis* from below.
11–13.—Middle Caudal Vertebra of *Acanthopholis*.
15.—Cervical rib of *Acanthopholis*.
16.—Small Caudal Plate of *Acanthopholis*.

PLATE VIII.

1.—A third Dorsal Vertebra of *Acanthopholis* from below.
2.—Phalanges of hind-foot of *Acanthopholis*.
3–4.—Dermal Plates of *Acanthopholis*.

Some Cretaceous Echinoidea from Jamaica.

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(PLATE IX.)

I. INTRODUCTION.

A SMALL collection of Echinoids from Jamaica, collected from horizons reputed to be Cretaceous, was sent me in August, 1922, by Dr. C. T. Trechmann. Pressure of work unfortunately delayed completion of my study of the specimens, so that my stratigraphical conclusions were not ready in time to be incorporated in Dr. Trechmann's two papers on Jamaican Geology, published in

this Magazine in September and November, 1922. However, the appearance of those papers has given a convenient stratigraphical basis for this contribution; and, although the Echinoid evidence seems to point to different conclusions from those deduced from other features, no serious part of his contentions is affected. Indeed, when it became obvious that my report would be too late, an actual advantage accrued; for, with more time, I have been able to look more closely into the morphology of some of the specimens, with results that seem to have important bearings on far wider questions than the correlation of West Indian horizons. While hoping that my conclusions may prove interesting and reliable as far as they concern stratigraphical problems, I attach greater importance to the purely palæontological deductions here introduced. If these should be substantiated, it looks as though the study of fossil Echinoidea, till now carried out on somewhat empirical lines, may begin to approach in precision that of Brachiopods and Ammonites. This may well cause grief to systematists, but it will make Echinoids better known as such, and of far greater value for purposes of detailed stratigraphy.

I have to express my thanks, not only to Dr. Trechmann for enabling me to handle such precious and interesting material, but also to Dr. Bather, F.R.S., to whom a few of the specimens were sent in the first instance. He began to work upon them, but found that his official duties were more insistent than mine, and generously forwarded his part of the material to me, so that the collection could be studied as a whole. It is particularly fortunate that the unique and critical specimen from the "*Barrettia*-beds" should have passed through Dr. Bather's hands, for its obscurity and importance are such that a second opinion is called for. We agree on the essential points of its systematic position, and in consequence I put forward the further deductions with the greater confidence.

Very few fossil Echinoids have been recorded from Jamaica. Jackson (1922, Foss. Ech. W. Indies, Carnegie Inst., Wash., pp. 5–6) lists six species only (two undetermined), all of which are assumed to be from Tertiary horizons. R. T. Hill (1899, B.M.C.Z., xxxiv, p. 118) records "Salenia" from the Blue Mountain series (partly Cretaceous) and "Acrocidaris" (l.c., p. 128) from the Cambridge Formation of Catadupa. There is a possibility that the "Salenia" refers to the new species of *Heterosalenia* described below; and, since Dr. Trechmann's specimens of this form were collected near Catadupa, it is very probable that the "Acrocidaris" (a curious member of a reputed Eocene fauna!) may be the same species.

Apart from these references by Hill, only eight species of Echinoids are recorded from the Cretaceous of the West Indies (*fide* Vaughan in Jackson, l.c., p. 110), all but one of these occurring in Cuba. However, several of the species referred to from the "Cambridge Formation" may have to be included in the list. Unless the specimens in Dr. Trechmann's collection that are specifically

indeterminable prove ultimately to belong to some of these types (which is at least possible), not one of the eight agreed Cretaceous species is represented in the Jamaican series. Whether the Cuban fossil identified by Cotteau with *Salenia scutigera* (Munst.) be rightly named or not, it cannot possibly resemble my new *Heterosalenia* if it bears the remotest likeness to *S. scutigera*. *Lanieria*, a well-known Cuban fossil, is in many ways very like the new genus *Metholectypus*, so that possibly some specimens of the latter type may have been confused with the former. But, speculation apart, the present position shows that in Jamaica there is an Echinoid fauna associated with Rudistan Pelecypoda that is quite distinct from that of neighbouring islands.

Dr. Trechmann's collection comprises seventeen specimens, representing three consecutive stratigraphical horizons and belonging to five (possibly six) genera. In accordance with his grouping of the beds concerned, the list, in ascending sequence, is as follows :—

Barrettia beds.	*Metholectypus trechmanni* gen. et sp.n. (1 specimen.)
Shales below the Rudist Limestones.	*Leiocidaris* sp. (1 specimen.)
	Diadematoid radiole. (1 specimen.)
	Hemiaster sp. (or spp.). (11 specimens.)
Rudist Limestones.	*Heterosalenia occidentalis* sp.n. (2 specimens.)
	Botriopygus rudistarum sp.n. (1 specimen.)

II. Description of Metholectypus trechmanni gen. et sp.n. (Pl. IX, Figs. 1–3.) Holotype (unique) : from the *Barrettia* Limestone, Haughton Hall, Green Island (Jamaica).

Measurements (in millimetres) :—

Diameter	(*c.*) 23·4	= 1
Height	(*c.*) 20·2	= 0·86
Apical system	1·3	= 0·056
Peristome	4·5	= 0·19
Periproct (length)	5·2	
,, (breadth)	3·7	
Ambulacrum (on ambitus)	3·7	= 1
Interambulacrum ,,	10·6	= 2·86

Corona slightly crushed, but almost globular. Obscurely subpentagonal in ambital outline, the ambulacra being slightly prominent, the interambulacra scarcely convex.

Ambulacra narrow, lanceolate. Perradial tract ornamented with three series of small tubercles forming oblique sets, as in *Holectypus*. The cast shows that a sharp carina passes internally down the perradial suture. Poriferous zones very narrow, straight, and crowded ; convergent near the peristome. Pore-pairs uniserial throughout, and equally congested throughout. Pores minute, quite homogeneous. Plates simple primaries throughout.

Interambulacra nearly three times as wide as the ambulacra, composed of broad, very low plates (about thirty in each column), corresponding to about four ambulacrals each, maintaining a fairly constant height (about 1 mm.) throughout. Tubercles very small

and inconspicuous, of practically the same dimensions throughout, set in deep areolæ scarcely wider than themselves. The "median tubercle series" (no more conspicuous than the others) is placed nearer the adradial margin of each column. The serial distribution of the tubercles is on the pattern found in the Pygasteridæ, Holectypidæ, and Discoidiidæ; the interradiad series (? maximum number 6) forming transverse rows, while the adradiad series (maximum number 4) form a chevron.

Apical system very minute, not very well preserved. Four relatively large genital pores, the posterior pore absent. Genital 5 certainly present, small and imperforate. Madreporite practically central, apparently restricted to genital 2. The whole system seems identical in character with that of Jurassic Holectypidæ, but is very much reduced in proportionate size.

Peristome sub-circular, its margin the lowest part of the corona. In position and proportions like that of *Amblypneustes ovum* or *Lanieria lanieri*. Possible traces of shallow branchial incisions.

Periproct elongate, oval, adapically acuminate. Situated on the adoral surface (i.e. below the ill-defined ambitus, but on a steeply rising portion of the test); separated from the peristome by not more than one millimetre of test.

Notes on the specimen.—A certain amount of crushing has made measurements somewhat approximate, and probably the height was originally a little greater than now. The test still exists over most of the surface, but two small regions are decorticated. Local incrustation obscures details over much of the remaining test, and the exposed parts seem to have been severely weathered. As a result, a first view gives the impression that no ornament or structure is visible; but after preparation and staining (partly carried out by Dr. Bather) the pores, sutures, and main tubercles have become traceable over a considerable and fully representative area. There is nothing to suggest the existence of internal carinæ as in *Discoidea*; indeed, such evidence as appears seems to prove their absence. (See Pl. IX, Fig. 3.)

Affinities of the species.—In general facies, and in many details, *M. trechmanni* shows very close agreement with *Lanieria lanieri* (Cott.). This resemblance is enhanced by the geographical proximity of the two types, one from Jamaica and the other from Cuba. The two species agree in size, globularity, peristomial, and periproctal qualities, tuberculation, and in the congestion of ambulacral and interambulacral plates.

But there is no question that generic differences exist, and hence the species must be considered distinct. The apical system of *Lanieria* is that of a *Coenholectypus* (with five large genital pores); that of *Metholectypus* is that of an *Holectypus* s. str., with the posterior genital imperforate. More important (in my estimation) is the fundamental contrast in ambulacral structure. There is no difficulty in determining that the ambulacrals of *M. trechmanni*

are simple primaries from the apex to the actual margin of the peristome; while those of *Lanieria* are grouped (with demi-plates) on the Pyrinid plan over the greater part of the areas. Not only does this feature sharply distinguish the new form from *L. lanieri*, it is also sufficient to separate it from *Holectypus*. I am not perfectly satisfied that some species of *Coenholectypus* may not show comparable simplification of ambulacral structure (I hope to determine this point shortly), but in any case the apical system shows that this Jamaican form is not to be classed with *Coenholectypus*.

There is no other species with which comparison seems useful; but it is a regrettable fact that, with incompletely preserved material, it would be practically impossible to distinguish between *M. trechmanni* and *L. lanieri*.

III. The Genus Metholectypus nov.

Diagnosis.—Echinoidea, Euchinoidea, Holectypoida, Holectypidæ. Small, sub-globular, with no defined adoral surface. Ambulacra narrow, lanceolate, with serial tubercle rows; poriferous zones narrow, flush; pore-pairs congested, absolutely uniserial, pores simple, homogeneous; plates simple, lath-like primaries throughout. Interambulacra wide, with very numerous, low, unbent plates, ornamented as in *Lanieria*, with the main tubercle-series nearer the adradial margins. Apical system minute, with five genital plates, four genital pores, and central madreporite. Peristome central, sub-circular, with faint branchial incisions. Periproct ovoid, acuminate adapically, almost in contact with the peristome. Genotype: *M. trechmanni* sp.n., Cretaceous, Jamaica.

Discussion.—*Metholectypus* is unquestionably an Holectypoid, and, in spite of its absolute ambulacral simplicity, can be placed in the Holectypidæ without undue straining of the family diagnosis. The three features of outstanding interest in the new genus are its extraordinary superficial resemblance to *Lanieria*, its lack of ambulacral complexity, and its imperforate posterior genital.

Is the resemblance between *Metholectypus* and *Lanieria* due to "heterogenetic homoeomorphy", or is the difference between them an effect of "homogenetic heteromorphy"? These are antithetic questions of no small importance, but exceedingly difficult to answer with confidence. At the outset, it may be pointed out that in this case we meet with a problem not unlike that discussed below in respect of *Heterosalenia*. There the new Jamaican species is *specifically* a *Hemicidaris*, but its *generic* qualities are quite different. Here *M. trechmanni* is practically identical with *Lanieria lanieri* in specific features; but in generic, and even family, characters the two forms are widely sundered. Save for the absence of the fifth genital pore in *Metholectypus* (a merely quantitative defect), the two species must have borne the same physiological relations to their environments. It is hardly too much to suggest that they have reached similar destinations by different routes.

Very probably their agreement in adaptive characters may be ascribed to environmental influence, in which case it is at least reasonable to postulate that they may have been contemporaries.

A possible answer to the two preceding questions can be given, but the evidence is less conclusive than could be desired. The apical system of *Lanieria* is exactly that of a *Coenholectypus*, but its ambulacral structure is far in advance (as regards quality and quantity of complexity) of that of any Holectypid, having reached a condition normal to the latest and sole surviving set of Holectypoids, the Echinonëidæ. The apical system of *Metholectypus* is "Jurassic" in character, and its ambulacral structure is far less elaborate than in any ordinary Holectypoid. May these contrasts not imply that *Lanieria* is an offshoot from the *Coenholectypus* stock, which has a *progressive* (though apparently fatal) trend, while *Metholectypus* is another offshoot from the same stock with *regressive* tendencies and no better success?

It is a remarkable fact, highly significant in this connexion, that *Macropygus*, the last effort of the Pygasteridæ, has complete ambulacral simplicity, and that its antecedents show a definite and steady reduction in plate-grouping. It seems impossible to account for this state of affairs, save on the hypothesis that the Pygasteridæ, a non-progressive group, underwent slow, and ultimately complete, phylogerontic simplification. Surely the same holds in the case of *Metholectypus*; but in that genus the genital system has followed the ambulacra in reversion to earlier standards.

If this suggestion is correct, *Lanieria* and *Metholectypus* would both represent "despairing efforts" of the dying Holectypid stock, the former with short-lived but whole-hearted progress in certain directions, the latter with unmitigated reversion. Sudden specialization of generic value seems a fairly constant precursor of extinction in a stock. The Triassic Spiriferids and Cretaceous Ammonoids show this condition very clearly, and many other cases are on record. In both the cases cited, morphogenetic complication of one series of structures is often coupled with simplification of another. Hence the suggestion that *Lanieria* and *Metholectypus* represent divergent "end-forms" of the Holectypidæ, the one over-elaborated and the other over-simplified, seems in accord with expectation. I feel certain that both were derived from the *Coenholectypus* stock.

Stratigraphical indications.—It is impossible to be dogmatic as to the horizon from which a new genus has been collected when no satisfactory independent evidence is available. But, if there is any truth in the biological arguments of the preceding sentences, it seems fair to suggest that *Metholectypus* and *Lanieria* may have been approximately contemporaneous. Opinion seems agreed that *Lanieria* is a Cretaceous form, but no greater precision has been arrived at. Arguing on purely systematic grounds, the nearest ally of *Lanieria* is *Discholectypus* Pomel, from the Albian of Algiers.

I have no intention of stating a definite belief that the *Barrettia* beds of Jamaica and the Cienfuegos beds of Cuba must of necessity occupy so low a place in the Cretaceous sequence; but in view of the indications of horizon afforded by the Echinoids of the overlying Jamaican series, it seems important to bear in mind the possibility that the *Barrettia* beds (at least) may occupy a very considerably lower position than that hitherto ascribed to them.

In any event, *Metholectypus* is one of the Holectypidæ. The only Holectypoid family known to have survived the Mesozoic era is the wholly different group of the Echinonëidæ. Hence it is as certain as such matters can be that the *Barrettia* beds are not post-Cretaceous; but their true place in the Cretaceous system is not demonstrable on the evidence of *M. trechmanni* alone.

IV. Echinoids from the Shales Below the Rudist Limestones.

(*a*) *Leiocidaris* sp. indet.

A single interambulacral plate from near the apex, with half of the contiguous ambulacram attached, was collected from these shales in the railway-cutting between Cambridge and Catadupa. The material is amply sufficient to prove the generic position, but is inadequate for confident reference to known species or for description as new. It seems not unlike *Cidaris* (*Leiocidaris*) *loveni* Cotteau, from the St. Bartholomew Limestone, said by Vaughan (l.c., p. 111) to be "undoubtedly Eocene". This last comment may or may not be correct (the species is ascribed to the Miocene by Lambert); but since there is no reason to believe that the two species are truly identical, and the genus *Leiocidaris* ranges from the Oxfordian to the present day with remarkable specific constancy, no question is here involved.

Another and far closer comparison can be made between this Jamaican *Leiocidaris* and *L. hemigranosus* (Shumard) from the Washita group of Texas. This American species would seem to come from an horizon roughly corresponding with the Cenomanian; so that such a comparison appears at first sight to carry the correlation of the Jamaican "sub-Rudist" shales to an improbable extreme in the opposite direction. I incline, however, to place more reliance on this second comparison than on the former one, both on the intrinsic similarity of the species and on the suggestive evidence of the associated Echinoids.

(*b*) *Diadematoid Radiole.*

This is a short fragment of the proximal end of a primary radiole from the same locality as the last. It has a very prominent milled collar, and a smooth shaft, cylindrical as far as it is preserved. It is probably the radiole of a *Pseudodiadema*, or of some allied genus, but it is possible that it may belong to *Heterosalenia*. Nothing definite can be said of it, either systematically or stratigraphically, as regards correlation.

(*c*) *Hemiaster* sp. (or spp.) indet.

There are eight of these from the shales below the Rudist Limestones in the railway-cutting between Cambridge and Catadupa (Central West Jamaica), and three from shales believed to occupy the same stratigraphical position occurring by the roadside between Port Antonio and Providence (East Jamaica). The former series are all small (averaging 2·5 cm. in long diameter) and probably represent a single species. The latter include two similar specimens, and one much larger (over 4 cm. long and about 3 cm. wide) which may perhaps be a different species.

All eleven specimens are shattered and distorted, and seem to have acted as nuclei to calcareo-pyritous concretions. Although small patches of the test-surface appear here and there on some of them, not a single example shows enough characters to permit of specific recognition. They bear a sort of resemblance to *Hemiasters* from the Comanche series of Texas, but nothing more definite can be said. Their small size and apparent abundance certainly suggest an horizon below the Senonian.

It is extremely unfortunate that none of the Echinoids from these shales are determinable, and one can hope that further collecting will bring to light some material that is better preserved, since it seems that they occur in greater abundance in this series than in those above or below.

ECHINOIDS FROM THE RUDIST LIMESTONES.

V. Description of Heterosalenia occidentalis sp.n. (Pl. IX, Figs. 4–6.)

Holotype: from the Rudist Limestone, Railway-cutting between Cambridge and Catadupa (Central West Jamaica). (Pl. IX, Figs. 4 and 5.) Paratype: same locality and horizon. (Pl. IX, Fig. 6.)

Measurements (in millimetres):—

	Holotype.		Paratype.	
Diameter	(*c.*) 34·6	= 1	32·7	= 1
Height	20·6	= 0·59	19·1	= 0·58
Apical system	12·5	= 0·36	10·6	= 0·32
Peristome	(*c.*) 16·6 (?)	= 0·48 (?)	17·7	= 0·54
Periproct (length)	5·7		(?)	
,, (breadth)	3·3		3·9	
Ambulacrum (on ambitus)	4·0	= 1	3·9	= 1
Interambulacrum ,,	15·3	= 3·82	15·5	= 3·9
No. of iamb. plates per column	8 (?)		7	= 1
,, amb. ,, ,,	(?)		70 (?)	= 7·0 (?)

Description of Holotype:—

Corona sub-circular in ambital outline (crushed so as to appear slighty elliptical), flattened adapically, almost vertical on the sides, flat adorally.

Ambulacra sinuous and narrow adapically and on the sides, wider and straight adorally. An exceedingly regular row of small,

prominent, scrobiculate granules borders each poriferous zone perradially (one granule to every three pore-pairs) in the narrow parts, and becomes a series of relatively large, scrobiculate, perforate and faintly crenulate tubercles at the ambitus, continuing thus to the peristome. An inner perradiad series of smaller granules occurs in each column almost throughout the narrow parts, alternating with the main series. The number of perradiad granules increases when the tubercles appear, and produces a granular chevron separating the tubercles of contiguous columns. The poriferous zones are fairly wide and depressed; the pore-pairs are uniserial almost to the peristome (becoming triserial there), each pair separated by a prominent granule. The plates are primaries throughout; those of the narrow portion are grouped into dyads (supporting the marginal granules) with single intervening plates (supporting the perradiad granules); below the ambitus the dyads absorb the single plates, producing triads as in *Hemicidaris* or *Acrosalenia*.

Interambulacra broad and convex. From 7 to 8 plates in a column. Each plate bears one large tubercle with a prominent perforated mamelon, narrow crenulated platform, and wide, shallow areola; the crenulations are so pronounced that they appear as a circlet of almost independent granules round the neck of the mamelon. Except in the apicad plates, the areolæ are confluent and are bordered by the remains of distinct scrobicular rings of well-spaced, scrobiculate secondary tubercles (four or five on each side of an areola), which are a little larger than the main granule series of the ambulacra. Very occasional minute granules intervene between the scrobicular rings and the adradial suture. The interradial regions are occupied by numerous irregularly placed and heterogeneous granules and tertiary tubercles, forming a granular interradial belt which, at the ambitus, may be as wide as the contiguous areolæ.

Apical system fairly large, very prominent. All the plates are deeply sculptured, with sunken as well as normal granules, and carious excavations mostly near the deeply impressed sutures. *Genital plates* subequal, the madreporic genital slightly larger than the rest. All are roughly quadrangular, the angles projecting into the interradii being very blunt. Genital pores very near the distal angles, with deep pits at their sides. Madreporite covering the greater part of its genital, multiporous and studded with granules. *Ocular plates* small, triangular or crescentic, but appearing almost square owing to excavation of the inner angles. Ocular I alone insert. *Suranal plate* part of a regular pentagon, much encroached upon by the periproct; otherwise similar to the other plates of the system.

Peristome imperfectly accessible. (See note on Paratype.)

Periproct relatively large, situated in radius I very near the margin of the apical system. Aperture crescentic, much elongated

in the direction 2, V, reaching to about the centres of genitals 1 and 5 and occupying almost half of the suranal pentagon. The margin of the aperture is widely bevelled: a regular series of deeply inset granules encircles the periproct; it is situated on the bevelled margin, so that the external edge of the periproct is slightly festooned.

Notes on the Paratype. (Pl. IX, Fig. 6.)

This specimen is more crushed and broken than the Holotype, but shows details of ornament much more clearly. Such part of the apical system as remains is beautifully preserved, and it has been possible to expose part of the peristome. This proves to be wide, with very small branchial incisions. These are approximately equidistant, but are situated well away from the adradial sutures. The ambulacra, with one or two proximal triserial groups of pore-pairs (enclosed in peripodia), make up less of the peristomial margin than do the interambulacra.

Affinities of the Species.

There can be no question that this is a *Heterosalenia*. Indeed, it resembles *H. martini* Cotteau, the genotype, so closely that its size and proportions provide the only marked distinguishing features. *H. occidentalis* is a full centimetre larger than *H. martini*, and the ratio of its height is about 0·59 as against 0·56. It is probable that the greater breadth of the interradial granular belt in the Jamaican form is to be correlated directly with its greater size. A further probable difference between the two species lies in the shape of the periproct, which is practically elliptical in *H. martini* and elongate-crescentic in *H. occidentalis*.

The general facies of *H. occidentalis* is suggestive of *Hemicidaris*, particularly *H. crenularis* (Lamarck), and it would be hard to separate the two on coronal features alone, save perhaps by the relative size of the branchial incisions; but the apical system (in size, constitution, and rugosity) and the periproct (in shape and position) are, of course, distinctive. The beaded edge of the periproct seems a generic character, and calls to mind the less abundant, but similarly placed, tubercles at the corners of the periproct of *Goniopygus*. This feature seems always liable to occur in members of the Hemicidaridæ; but it is far from universal in that family, and seems not to occur in any other group.

VI. The Genus Heterosalenia, Cotteau, 1861.

Heterosalenia was introduced by Cotteau (Pal. franç., cret., vii, pp. 96–8) as the second Cretaceous genus of his family of "Salenidées", to include the solitary and very rare *H. martini* (l.c., p. 97; pl. xxii, figs. 7–12) from the "Craie à Hippurites (Sénonien inférieure)" of Les Martigues. *H. martini* is, therefore, the genotype. In 1902, Savin (Bull. Soc. Stat. Isere (4) vi, p. 9) described *H. paquieri*, a new species from the Aptian. I have been

unable to see Savin's paper, and refer to it on the authority of Lambert. Until the description of *Heterosalenia occidentalis* just given, these were the only species that had been ascribed to the genus by their original authors. But Lambert and Thiéry (Essai nomencl. rais. Ech., fasc. iii, p. 176) in 1911 transferred to *Heterosalenia* two species from the Upper Corallian (Rauracien) of Germany described by Dames (Zs. D. geol. Ges., xxiv, pp. 132–5) as *Acrosalenia corallina* and *Pseudosalenia ottmeri*. As far as I am aware, the five species named in this paragraph are the only ones ever referred to *Heterosalenia*.

Before proceeding, it is necessary to point out a mistake in the lettering of Dames' Plate ix. According to his text, Figs. 2 (a–d) of this plate represent *Acrosalenia corallina*, and Figs. 3 (a–d) *Pseudosalenia ottmeri*. That these numbers have been transposed on the plate is evident when text and figures are compared. There is no doubt that *A. corallina* is illustrated in the figures labelled "3", and *P. ottmeri* in those labelled "2". This correction is important, since there is at least a possibility that Dames was right in believing that the two species are not congeneric.

Pseudosalenia ottmeri has a relatively large, very rugose, apical system, with a well-developed suranal plate and a bevelled and granulate border to the periproct. I suspect that the median position of the genital pores shown in Dames' figure 2 d is a mistake—the artist may well have been misled by some of the carious hollows on the plates. The indentations at the outer angles of the plates probably mark the sites of the genital pores. If this correction is admitted, the only serious difference between *P. ottmeri* and *Heterosalenia martini* consists in the almost axial position of the periproct in the former. A mysterious angle on the left side of the suranal plate in the figure suggests some error in drawing, since a re-entrant angle in a genital plate would be unique. It is possible that the suture in radius V should meet the projecting corner of the suranal plate; in which case, the periproct would be relatively shifted towards the right. But whether these suggested modifications of Dames' drawing are accepted or not (a question to be decided only by re-examination of the two specimens he used), I am in agreement with Lambert that *P. ottmeri* should be classed with *Heterosalenia*, subject to reservations made below. On the other hand, *Acrosalenia corallina* (Dames, l.c., pl. ix, fig. 3 d) has the apical system relatively small, composed of unsculptured plates ornamented with serially distributed granules, a very small subquadrangular suranal plate, and an extremely oblique periproct devoid of a granular border. The obliquity of the periproct is the only point of resemblance between this apical system and that of a typical *Heterosalenia*. *A. corallina* is a mysterious form, and I am far from confident in challenging its transference to *Heterosalenia*; but I certainly hesitate to accept it. Perhaps the unique example was an abnormality; but without the specimen nothing

can be said. In any event, it seems clear that at least one of Dames' Corallian species (*P. ottmeri*) is a genuine *Heterosalenia*, so that the foregoing comments leave the stratigraphical aspects of the genus as before.

The time-range of *Heterosalenia* is surprising. Upper Corallian, Aptian, and Coniacian (omitting the assumed Maëstrichtian date for the Jamaican form) seem like three roughly equidistant points on an enormously long line. At each of these widely separate times, one or at most two specimens have been found; in all cases sufficiently alike to leave no doubts as to their generic position. Further, in the cases of the three species known to me, there appears to be a recognizable progression in two characters. *H. ottmeri* (Corallian) has a diameter of 14 mm., that of *H. martini* (Coniacian) is 25 mm., while that of *H. occidentalis* (? later) is 35 mm. *H. ottmeri* has the periproct practically in the axis III–5, obtusely oval; *H. martini* has it in the axis 1–3, also obtusely oval; *H. occidentalis* has it in the same position, but elongated. Two such orderly features of progression cannot fail to suggest that the three species concerned (and by assumption *H. paquieri* as well) form a true phyletic series, in spite of their disjointed chronological sequence. It may be argued that the extreme rarity of the known species makes intelligible, and even predicable, the long intervals where the genus is as yet unknown. But, when full weight is given to that argument, there still remains the surprising fact that *Heterosalenia* is not known from, say, the Neocomian or Cenomanian, horizons with teeming Echinoid faunas and at least as fully explored as those from which it has been collected.

All the three species under consideration (omitting *H. paquieri*, whose precise surroundings are unknown to me) were reef-dwellers. *H. ottmeri* is from the Coral Rag, *H. martini* from the "craie à Hippurites", and *H. occidentalis* from the "Rudist Limestones". At many horizons between the Rauracian and Upper Cretaceous similar reef-conditions were developed, and have been well explored. So that the wide gaps in the recorded sequence of *Heterosalenia* can hardly be ascribed to its peculiar requirements in the matter of environment.

With full realization of the danger of basing conclusions on negative evidence, I would submit that there is at least a *prima facie* case here for debating the question as to whether the several species of *Heterosalenia* may not be successive orthogenetic offshoots from a continuous stock rather than a lineage in themselves. Perhaps they were cast into similar moulds by some subtle requirements incidental to reef-life. Such a suggestion may be dismissed as speculative or grotesque, according to the temperament of the critic; but it requires disproof, or replacement by one more securely founded. It is fully agreed that, in the present state of knowledge, the only possible treatment of this series of species is to group them in a single genus. What place, then, in a systematic

scheme, can *Heterosalenia* occupy? Or, transgressing again into Utopian realms, in what phyletic series can the genus find a place?

Cotteau included *Heterosalenia* in the Saleniidæ, and was followed in this by Duncan. Few modern authors would agree with this plan. The "Calycina" include two manifestly distinct series, typified by *Acrosalenia* and *Salenia* respectively; the only common character being the persistence of suranal plates. Pomel (1883) placed *Heterosalenia* in the Diadematidæ, group Hemicidaridæ, section *a* (i.e. forms possessing an apical system like the Saleniidæ). This is a far more reasonable plan than that of Cotteau, and, with different nomenclature, is essentially that followed by Lambert and Thiéry (1911). As far as concerns this genus, Lambert's family Phymatresidæ corresponds to Pomel's Diadématidées; his subfamily Tiaridæ matches Pomel's Hemicidariens; while Lambert's "Tribu Pseudosaleninæ" is merely a name for Pomel's *a*. I am fully satisfied that this position for *Heterosalenia* is as nearly natural as can be attained at present.

The relations of *Heterosalenia* were well expressed by Cotteau on its introduction. He says (l.c., p. 97) "Les *Heterosalenia* sont aux *Pseudosalenia* ce que les *Salenia* sont aux *Peltastes*". The analogy appears exact, but what does it mean? If we follow the modern course, laying stress mainly on coronal characters, the first two genera and the last two genera form pairs. But there seems no logical reason why the position of the periproct should not be as important as the grouping of ambulacral plates or perforation of tubercles. If it were given preference, *Heterosalenia* and *Salenia* would form one group, and *Pseudosalenia* and *Hyposalenia* (olim *Peltastes*) another. Alternative but intersecting schemes of classification of this kind are too common to be accidental. They point to the existence of some measure of independence between morphogeny and phylogeny, whereby the difficulty of tracing lines of actual descent is vastly increased. The particular instance under consideration is a typical example of its kind, but possibly provides a slender clue for guidance.

In the Faringdon Greensand (? Aptian) of West Berkshire, one of the commonest fossils is *Hyposalenia wrighti* Desor. Among the rarities of that prolific facies are specimens of *Salenia*. After minute investigation of many examples of both these types, I have failed to find specific, or even varietal, differences between *H. wrighti* and "*Salenia* sp.". They fall into different genera on periproct position, and on that alone—when specific features are considered, they are identical. Two alternative explanations of this anomaly seem possible. Either the special conditions represented by the Faringdon deposits caused absolute convergence of two distinct, but ultimately homogenetic, types; or else the actual position of the periproct in relation to the axis was non-essential, and examples of the dominant *Hyposalenia* were always liable to produce occasional recessive *Salenia*! All my recent experience among

Echinoids encourages me to accept the latter alternative. I am prepared to believe that these Faringdon *Salenias* may have been members of the same broods as some of the *Hyposalenias!* Alas for systematics!

It is well known that the actual anal aperture of Regular Echinoids is very usually situated behind, and to the right of, the centre of the periproct. A sympathetic tendency to backward migration of the periproct itself is commonly found, reaching its climax in production of "Irregularity". The studies of Jackson (1912, Phylogeny Ech.; 1914, Studies of Jamaica Ech.) on the "insertion" of ocular plates show the existence of much individual variation (not necessarily haphazard) in the degree of eccentricity of the periproct in many forms; but also of a general tendency for oculars I and V to become insert as a progressive feature. Further, Jackson has determined that in the Hemicidaridæ, Centrechinidæ, Saleniidæ, Echinidæ, and most other Regular families, ocular I is the earlier of these two plates to be reached by the periproct. This seems to imply a constant tendency in these families for the periproct to pass backwards and to the right. Under such circumstances, when some species of *Acrosalenia* (e.g. *A.* "*decorata*") show "precocious" backward movement of the periproct, it seems reasonable to assume that occasional individuals or groups might develop exaggerated *lateral* migration; so that the suggested relation of the Faringdon *Salenia* to its companion *Hyposalenia* is not at all fantastic.

The purpose of the preceding digression is to show that we cannot entirely rule out the possibility of *Heterosalenia* representing an occasional phase of Pseudosalenine, or even Tiarid, evolution. The constant association of apical rugosity and a beaded periproct-margin with lateral obliquity of the periproct may perhaps imply that some Mendelian control affects this assemblage of characters. Most hereditary qualities occur in groups. I am strongly inclined to believe not only that *Heterosalenia* is a composite series of orthogenetic offshoots from some more familiar type, but that *Pseudosalenia* is its complement with purely backward periproct excess. As to the stock from which these two series of variants were liable to emerge, little confidence can be expressed; but *Hemicidaris* seems, on the balance of characters, more probable than *Acrosalenia*.

Stratigraphical indications.—The latest member of *Heterosalenia* recorded is the genotype *H. martini*, which occurs at or a little above the top of the Turonian. The other known species are from the Aptian and Rauracian. The specific resemblance between *H. occidentalis* and *H. martini* is so close (omitting reference to mere size) that anyone concerned with the new species alone, and uninfluenced by previous stratigraphical arguments, would claim the same horizon for them both. This would make the part of the Jamaican Rudist Limestones from which *H. occidentalis* was collected

either uppermost Turonian or lowest Senonian. The arguments given above might, if their tenour were accepted, vitiate this conclusion; but no possible "ancestor" for *H. occidentalis* is known from any higher horizon; so that this suggestion is the only one that can be given on the evidence available. At any rate, it must be admitted that the general character of the species, recalling Jurassic rather than Cretaceous types, is strongly antagonistic to any assumption that the Rudist Limestones are post-Cretaceous. *H. martini* was far and away the latest known member of its *family* up till now, so that (in default of proof) any attempt to extend the range of the genus beyond the limits of the Mesozoic would be unjustifiable and even absurd.

VII. Description of Botriopygus rudistarum sp.n. (Pl. IX, Figs. 7–9.)

Holotype (unique) from the Rudist Limestone, Great River Valley, below Catadupa, Jamaica.

Measurements (in millimetres):—

Antero-posterior diameter	36·5 = 1
Maximum transverse diameter	30·8 = 0·84
From Apex to Anterior Margin	16·0 = 0·44
Height	22·6 = 0·62
Peristome (III–5)	3·8 = 0·10
,, (maximum)	5·0 = 0·13
,, (centre to Anterior Margin)	16·2 = 0·45
Periproct (III–5)	7·1 = 0·19
,, (transverse)	4·0 = 0·11

Test elongate, tumid; greatest breadth a little in front of ambulacra I and V: forward thence the sides converge slightly to ambulacra II and IV, and then close in sharply in a semi-circular curve, forming the anterior margin; backward, the convergence is rapid and almost direct, the posterior point being slightly truncated by the periproctal sulcus. Sides almost vertical; apical surface flattened, adoral surface almost flat.

Ambulacra similar (save in length), II, III and IV near together, I and V more widely apart. Petals very feeble, extending without defined limits to the edge of the adapical surface. On the sides the ambulacra maintain almost the same width as the petals, and just near the peristome expand very slightly into feebly impressed phyllodes. Petaloid pores small, inner series round, outer slightly elliptical, pairs connected by short, deep grooves; all other pores very minute, uniserial except in the phyllodes. Areas practically flush with surrounding test, but petals and phyllodes very slightly raised and depressed respectively.

Interambulacra wide, dissimilar. Areas 1 and 4 especially tumid along lines posterior to their interradial sutures; area 5 obtusely carinate adapically just above the periproct, sulcate immediately below it, and tumid adorally; areas 2 and 3 narrower, with hardly any tumidity except in the floscelle. Tubercles of the adapical surface small, numerous, widely spaced, situated in deep but narrow

areolæ, tending to form oblique lines, separated by fairly wide minutely granular areas. Those of the ambitus and adoral surface are hardly appreciably larger, the former crowded, the latter very widely spaced; a sort of plastronal arrangement in area 5.

Apical system slightly forward of the centre, minute. No details visible.

Peristome almost opposite the apical system. Practically flush, elliptical, very oblique, elongated in a direction between II-4 and 2-V.

Periproct marginal, but directed downwards. Elongate, ovoid, acuminate adapically. Margin slightly invaginated, with a short sulcus below, extending to the edge of the adoral surface.

Affinities of the Species.

It seems certain that this species is congeneric with *Botriopygus obovatus*, although the petals and phyllodes are so feebly developed. The same feature distinguishes it from *B. alabamensis* Clark; and, indeed, from all other species of the genus known to me. Further, its height is unusually great, and gives it something of the facies of an *Echinolampas*. But the oblique peristome and vertically elongate periprôct are enough to leave little doubt as to its place in *Botriopygus*.

Stratigraphical Indications.

When d'Orbigny established the genus *Botriopygus*, he included in it species ranging from the Neocomian to the Turonian. But his Turonian species are not congeneric with the earlier forms, and it is with those that *B. rudistarum* must be grouped. *B. alabamensis* is from the Ripley group (correlated with the Upper Senonian); it is the least like *B. rudistarum* of all forms ascribed to *Botriopygus*. On general grounds it is to be inferred that the Jamaican species is less advanced than *B. alabamensis*, but this does not, of course, preclude the possibility of the two forms being contemporaneous. However, on direct and independent comparison, *B. rudistarum* suggests affinity with Lower Cretaceous rather than Upper Cretaceous species.

VIII. Summary and Conclusions.

(*a*) *Palæontological.*—A new genus of the Holectypoida, *Metholectypus*, is described. Its only known species, *M. trechmanni* sp.n., shows remarkable superficial similarity with *Lanieria lanieri*. It is argued that these two genera may be divergent end-forms of the *Coenholectypus* stock.

A large species of *Heterosalenia* (*H. occidentalis* sp.n.) gives occasion for discussion of the affinities of that genus. Arguments are put forward to show that *Heterosalenia* and *Pseudosalenia* may be composite genera, including occasional orthogenetic offshoots from a persistent stock (perhaps *Hemicidaris*) consisting of individual, or group, cases of an exaggeration of fundamental tendencies that may be accounted for on a Mendelian basis. A

similar relation is believed to unite and disintegrate *Salenia* and *Hyposalenia*.

A new species of *Botriopygus* (*B. rudistarum* sp.n.) shows a very simple stage in the production of petals and phyllodes.

(*b*) *Stratigraphical.*—Since all the determinable species and one of the genera are considered to be new, exact comparison of faunas is impossible. This is the only crumb of comfort that I can give to Jamaican stratigraphers. They must make what use of it they can; but to a palæontologist it is almost immaterial. The two alternative published views as to the horizons of the three beds from which the Echinoids come are (i) Trechmann's opinion that the whole series is probably Maëstrichtian, and (ii) Hill's belief that the lower part is Cretaceous (presumably uppermost) and the upper part Eocene. In the light of the results derived from study of the Echinoids, these two views seem very little different, and both untenable.

The solitary specimen from the *Barrettia* beds (*Metholectypus trechmanni*) invites comparison with *Lanieria* from Cuba. The horizon of the latter is not known definitely, but is accepted as Cretaceous. The only other member of the family to which *Lanieria* belongs is Discholectypus, an *Albian* genus.

The specimens from the shales overlying the *Barrettia* beds and beneath the Rudist Limestones are *Leiocidaris* sp. and *Hemiaster* sp. The former is closely comparable with *L. hemigranosus* from an approximately *Cenomanian* horizon in Texas. The latter, whose preservation prevents satisfactory comparison, suggests affinity with *Cenomanian* or *Turonian* species of *Hemiaster* rather than with any from higher horizons.

The excellently represented species from the Rudist Limestone are *Heterosalenia occidentalis* and *Botriopygus rudistarum* spp.n. The latest previous record for *Heterosalenia* is from the *base of the Senonian*, and that represents by a long way the latest appearance of the family to which it belongs. Even if the explanation of the "genus" given above (sect. vi) be admitted, the fact remains that no form from which *H. occidentalis* could be derived is known from above the "Coniacian". *Botriopygus* is chiefly developed in the Lower Cretaceous, but seems to range almost throughout the period. The simple structure of the new species points to a lower, rather than a higher, position.

This record of simple deduction obviously excludes all likelihood of a Tertiary date for any part of the sequence considered. It fails, equally, to indicate any specially high Cretaceous zones. Further, it can hardly be a coincidence that the stages suggested by the Echinoids are in conformity with the known sequence of the beds. The literal evidence is, then, that we have in these three members of the Jamaican Cretaceous system a time-range from the base of the Upper Cretaceous to about the base of the Senonian. Some latitude in interpretation may be allowed, but it does not seem that

Mäestrichtian could be included, at least for the parts of the Rudist Limestone represented by the Echinoids.

This result came as a great surprise to me ; and it will, I fear, give a shock to West Indian stratigraphers. But with the evidence available " I can do no other ". It is possible, of course, that the West Indies was a region to which belated forms retreated to die, so that these types were surviving long after their extinction elsewhere ; but there is no existing authority for assuming this—I suggest it out of sympathy with those workers to whom my conclusions may be disconcerting.

EXPLANATION OF PLATE IX.

FIG.

1.—*Metholectypus trechmanni* gen. et sp. nov., Holotype. Adapical surface. Note the four genital pores.
2.—*M. trechmanni.* Adoral surface. The branchial slits are not so clearly shown in the specimen.
3.—*M. trechmanni.* Posterior surface. Note apparent absence of internal carinæ.
4.—*Heterosalenia occidentalis* sp. nov., Holotype. Adapical surface.
5.—*H. occidentalis.* Same specimen. Side view (amb. I).
6.—*H. occidentalis.* Paratype. Adapical surface.
7.—*Botriopygus rudistarum* sp. nov., Holotype. Adapical surface. The apical system is broken.
8.—*B. rudistarum.* Adoral surface. Note obliquity of peristome.
9.—*B. rudistarum.* Posterior surface. The prominence near the apex is accidental.

All figures are approximately natural size. For true dimensions see descriptions of the species.

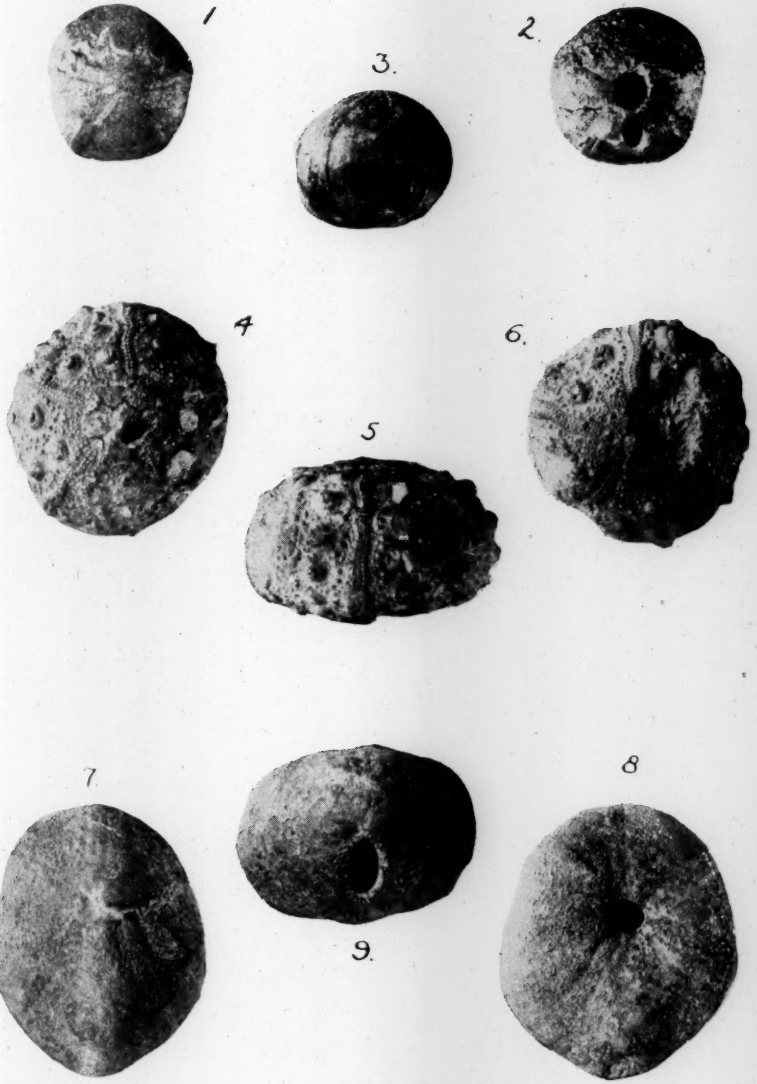
The Relationship of the Rugosa to the Hexacoralla.

By Professor N. N. Yakovlev, Petrograd.

IN this paper I propose to deal with the question set forth in the title in connexion with the recent works of different authors. Owing to the difficulties of international communication, I was unable until quite recently (1922) to consult the general works on the *Rugosa* corals published by Faurot, Jaekel, and Robinson.[1]

I will begin with a discussion of Jaekel's work, which, although the latest to appear, was written independently of the other works, with which the author was not even acquainted. Jaekel constructs the first stage in the arrangement of the septa in the corallum of *Rugosa* (fig. 14, p. 244) in a way that has not hitherto been established by anybody else. He bases his conclusions on the fact that in the *Rugosa* " the chief and counter septa are developed quite differently, whereas the alar septa always retain their determining (massgebend) significance in the structure of the

[1] L. Faurot, " Development et Symmétrie des Polypiers Coralliaires ": *IXe Congrès international de Zoologie, Monaco,* 1913 (1914), pp. 278–84. W. J. Robinson, " The Relationship of the Tetracoralla to the Hexacoralla ": *Trans. of the Connecticut Acad. of Arts and Sciences,* 1917, pp. 149–200. O. Jaekel, " Über Anthozoen.," *Palæontolog. Zeitschr.,* Bd. ii, Heft iii, 1918, pp. 232–50.



H. L. H. *Phot. et del.*

To face p. 216.]

theca".[1] This remark of Jaekel's regarding the relative significance of the chief and counter septa as compared with the alar septa can only concern the adult stages of the corals, and even then only to a certain degree, since the chief and counter septa are never absent, but may only be sometimes weakly developed from the periphery of the transverse section to the centre. This usually stands in connexion with the development of *fossulæ* in the plane of symmetry, which suppress the development of the primary septa in it. Even in that case, however, the primary septa in the plane of symmetry never disappear altogether, being distinctly marked on the external surface of the wall. As regards the first stages of the coral, there is no foundation for the statement, according to which permanency of the alar septa is prevalent. In none of the works of the authors who described the first stages (Duerden, Carruthers, Faurot, T. C. Brown) do we find that the septa lying in the plane of symmetry are absent or weakly developed in the first stages; on the contrary, they appear simultaneously with the alar septa, develop in the same way, or may even predominate over them by preceding them in appearance.

Jaekel, however, uses this supposition regarding the predominant significance of the alar septa as the foundation of his further discussions on the development of bilateral symmetry in the *Rugosa* and *Zoantharia* in general. Jaekel holds that this symmetry is due to the origin of the *Rugosa*, and Zoantharian corals in general, from free-moving, bilaterally symmetrical, vermiform animals. Fixation must have taken place in such a way that the mouth and anal aperture became disposed on the distal end of the attached animal, opposite to the substratum, similarly to the case in echinoderms. In echinoderms, however, the mouth and anal aperture remain separated, whereas here, according to Jaekel, they became fused, so that one end of the elongated mouth opening of the coral-polyps corresponds to the primary anal, and the other end to the mouth-opening of their free-moving ancestors. The union of these openings was effected by the fusion of the anterior and posterior ends of the body, which were directed upwards from the substratum, the intestine becoming the gastral cavity, and the ends of the body having become adjacent with their ventral surfaces fusing together. The fused walls, according to Jaekel, correspond to the two alar septa of the *Rugosa*. The unequal development of the secondary septa in the chief and counter quadrants (and of the quadrants themselves) on either side of this partition, which originated by fusion, is connected by Jaekel with the supposed difference between the anterior and posterior ends of the body of the vermiform ancestors of the *Rugosa*. The bilateral symmetry which thus appears in the *Rugosa* as a heritage from its free-moving ancestors, becomes obscured in their later descendants—the *Hexacoralla* corals. The lateral attachment of the corallum, which was first demonstrated

[1] pp. 242–4.

by me in *Rugosa,* is corroborated by Jaekel,[1] who figures it in a diagram of the coral on p. 237, but regards it only as one of the extremely original peculiarities in the growth of the Tetracoralla (" ein weiterer höchst bemerkenswerter Umstand für das eigentümliche Wachstum der Tetrakorallen ").

As regards the explanation of the origin of the characteristic features of the *Rugosa* (first of all of the pinnate arrangement of the secondary septa with regard to the primary ones) based by me on the lateral attachment, Jaekel considers this explanation to be inadequate. He does not enter into a detailed discussion of it, but bases his negative judgment on the view, ascribed to me, that the coral first assumed its curved form in the shape of a horn, and only then became attached with the convex side. Nobody else ever ascribed such views to me, as I had definitely stated that *the curved condition was the result of fixation,* although different authors, viz. Duerden, Stanley Smith, Filliozat, Dacqué, and others, certify their knowledge of my works.

In the only paper of mine to which Jaekel refers (" Die Entstehung der charakteristischen Eigenthümlichkeiten der Korallen *Rugosa* "), although he was apparently also acquainted with another paper of mine[2] (" Ueber die Morphologie und Morphogenie der *Rugosa* "), it is nowhere said that the corallum attaches itself when already *bent* in the form of a horn; on the contrary, on the same page of this paper I wrote: " Als Ursache des gebogenen Zustandes des Polypariums Rugosa erscheint seine Anheftung mit der Seitenwand." And, further, on the same page the following appears: " Das mit der Seitenwand angeheftete Polyparium bog sich dann, in Folge des Strebens, die Mündung vom Boden zu entfernen, von ihm zurück."

It is possible, however, that on the second page I expressed myself somewhat unguardedly as follows: " Die Anheftung mit der seitlichen, am wenigsten gekrümmten Oberfläche," and, further: " Die Anheftung mit der konkaven Seite." It is but natural, however, to say, for the sake of brevity, that the coral attaches itself with its concave side, instead of saying " the coral attaches itself with the side which later becomes concave ", especially if this has to be repeated frequently. On the same page (p. 235), where Jaekel expressed his doubt as to the correctness of my supposed statement that the coral first became bent and then attached itself, and a few lines below he says the following regarding a coral from Wisby: " Finde ich z. B. fast alle Exemplare mit der konvexen Seite nach der Spitze auf kleinen Bryozoenstöcken aufgewachsen." I was conscious of the inconvenience of the expression " attachment with

[1] " Feststellung von Yakowlew, von deren Richtigkeit man sich vielfach überzeugen kann " (p. 234). " Die tatsächlichen Angaben Yakowlews besonders betreffs der Anheftung und des Wachstums der Rugosa kann ich durchaus bestätigen " (p. 235).

[2] Judging from the fact that he mentions a drawing from that work.

the convex side", and tried as far as possible to avoid using it, in which I believe I succeeded in my later works. I repeat, however, that nobody except Jaekel misunderstood my meaning.

I again adduce a diagram explaining the development of the septa in the *Rugosa*, giving details of this development *in a series* of stages, which I had not done before.

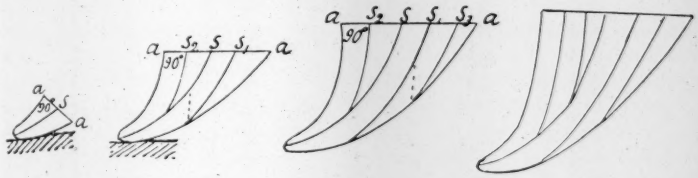


FIG. 1.—Scheme of development of the septa in the *Rugosa*. First stage (left) with only four primary septa. The further development corresponds to the scheme given by me in the GEOLOGICAL MAGAZINE in 1917. Interrupted lines indicate the direction in which the secondary septa (S_1 and S_3) would have developed if the primary septa (S) were absent.

We may now return again to Jaekel's own views. Regarding the origin of new secondary septa in pairs and in two regions—in the chief quadrants and in the counter quadrants—Jaekel first of all attempts to establish that the origin of the new septa coincides with the formation of transverse constrictions (fig. 1, p. 236). Jaekel does not explain what constrictions he had in view. I know of no constrictions which could be designated by this name, except the ones which appear in the process of so-called rejuvenescence of the coral, but they are not numerous, and are followed not by an increase in the number of septa, but, on the contrary, in connexion with the diminution of the diameter of the theca, their number is diminished. There remain slight constrictions or hardly visible indications of such, due to transverse wrinkles of the epitheca. It is quite impossible, however, to place these wrinkles, which vary considerably in degree of development, in any connexion with the development of the septa. If Jaekel discovered a correspondence between the number of septa and constrictions in some Cyathophyllid from the Silurian system of Gotland, this single fact does not justify any general conclusions. At first Jaekel (p. 236) expresses his views regarding this relation between the septa and constrictions in a passing manner and rather cautiously (" wie es scheint "), therefore his far-reaching conclusions from this correlation appearing on pp. 249 (at the bottom) and 250 are rather unexpected. The appearance of secondary septa in pairs in two regions (at the chief and counter septa) he explains as the result of an increase in the number of metameres from both sides of the segmented vermiform body of the ancestors of the corals. The origin of the secondary septa is, however, easier explained in the following manner: the conic form and curved shape of the coral, with its growth and

broadening at the mouth, causes a dilated space to be formed, firstly between the chief septum and the secondary septum closest to it and bent at an angle to the latter, and secondly between the alar septum and the secondary septum closest to the former in the alar quadrants. The filling of these free spaces with new-formed septa presents a necessity. The cause leading to the arrangement of the secondary septa at an angle to the chief and the alar septa was stated in my previous works, viz. it is their development under the influence of mechanical conditions due to the pre-existing primary septa, and in connexion with the bent position of the coral and a definite inclination of its mouth.

Thus the general conclusions to which Jaekel arrives, and which are based on two suppositions—(1) the greater constancy of the alar septa as compared with the chief and counter septa, (2) the correspondence between the external constrictions and the number of septa—have no foundation.

In assuming that the corals originated from a vermiform ancestor belonging to the *Coelomata*, Jaekel apparently based his view on the idea that the attachment of the animal to its substratum results in degradation and regression of its structure. In general, this view is correct with regard to the organs of locomotion and organs of sense of sessile animals.

Apparently, the usual supposition that the corals originated from free-living gastrula-formed Coelenterata did not satisfy Jaekel, as it did not account for any visible degradation either in the locomotory organs or the organs of sense. Probably, on account of this, and in accordance with his general belief in the importance of processes of development involving a lowering of the organization, e.g. as the result of interruption in the ontogeny, Jaekel came to regard the *Coelomata* as the ancestors of corals. These views found further development in the idea of metamerism, of attachment accompanied by bending of the body and fusion of its ends.

We shall again return to the question regarding the free-living ancestors of corals in connexion with Faurot's paper, and, meanwhile, I wish to draw attention to two other unsuccessful conclusions of Jaekel, which are of a minor character.

In making a "revision" ("Umdeutung") of the sections produced by T. Brown and myself, Jaekel gives an altered drawing of the section of *Lophophyllum proliferum* in fig. 7. In the drawing of the section "corrected" by him, the essential alteration is not the fact that the drawing is turned with the upper margin downwards—apparently that is the right interpretation of the words "in umgekehrter Stellung" given in the explanations under the figure—but the chief feature in the alteration made by Jaekel is presented by the fact that he perverted the succession of development in the primary quadrants lying in the plane of symmetry and adjoining the shorter of the primary septa. In his figure the new, secondary septa are directed *upwards* from the primary alar septa, whereas

in the lower quadrants adjoining the longer of the primary septa they run in the opposite direction. As a matter of fact, however, the development of the secondary septa in the chief and counter quadrants does not proceed in opposite directions to the opposite ends of the long diameter of the theca, but is always directed to one end, as is seen from fig. 8 given by Jaekel on the same page. This development can only be in one direction (cf. my scheme here, Fig. 1), since, on account of the conic bent form of the coral, the free space for the formation of new septa is formed on one side, both of the chief and counter quadrants, viz. usually on the side directed towards the convex surface of the coral. Therefore, Jaekel's fig. 7 presents an impossible case.

The second remark concerns Jaekel's discussions on the *Calceolidae*, on p. 238. Jaekel states that in the *Calceolidae* the position of the chief and counter septa cannot be determined on the external surface of the corallum on account of the development of the epitheca, which obscures the traces of the septa on the outer surface of the corallum. Jaekel finds the solution of the question regarding the relative position of the chief and counter septa of *Calceola* in the genus *Holophragma* from the Silurian system of Gotland, in which the chief septum is found on the flattened convex side. There is no doubt, however, that in *Calceola* the chief septum is disposed on the concave side, and not on the convex side, and it can be discovered there by removing the epitheca in the usual way—by etching or grinding.

According to Kunth and Neumayr (Die Stämme des Thierreichs, after Kunth), Jaekel would have found a distinct figure of *Calceola* with the counter septum on the flattened convex side; in Zittel and Haushofer's plates, there is a figure of *Calceola* with the chief septum on the concave side, and in Zittel's "Handbuch" the position of the chief septum on the concave side is mentioned even in the generic diagnosis of *Calceola*. I have also pointed this out in my paper: "Some notes on the *Calceolidæ*" ("Einige Bemerkungen über die *Calceolidæ*").[1]

Referring to my explanation of the origin of the characteristic peculiarities of the *Rugosa* corals, Jaekel finds it impossible to agree with it, as it has no physiological basis to support it. I do not think, however, that every explanation of morphogenesis should necessarily have reference to physiological data. Thus, for instance, Kammerer ("Allgemeine Biologie"), according to Semon, contrasts the physico-chemical factors of morphogenesis as elementary to the physiological factors which are the result of other excitations. My explanation is mechanical, i.e. physical, and therefore belongs to the first class, which renders any physiological explanation unnecessary.

We may now pass to Faurot's work. This author was formerly engaged in studying the development of the individual septa in

[1] "Studien über die Korallen *Rugosa*": *Mém. Com. Géol.*, Nouv. Sér. Livr. 96, 1914, Petrograd.

the *Rugosa*, and has now turned to its comparison with the development of the coralla of the conic *Hexacoralla*, namely the Turbinolia. In a small paper published in the *Transactions of the Ninth International Zoological Congress*, Faurot states that the view which holds that the six first septa appear simultaneously in the *Hexacoralla*, is erroneous, and that the development of these septa in the *Turbinolia* proceeds in the same order as in *Cyathokonia* belonging to the *Rugosa*: first, two septa appear in the plane of symmetry, and then five more pairs of septa are developed one after another in succession. It is only after this stage that differences in the development between the *Rugosa* and *Hexacoralla* make their appearance. The difference lies in the fact that whereas in *Turbinolia*, which is provided with twenty-four septa, a strictly six-radial symmetry is established, in *Cyathaxonia* the bilateral symmetry is retained.

On this account Faurot regards the bilateral symmetry in the *Rugosa* and *Hexacoralla* as a primary phenomenon, comparing them in the first stage of development of the septa (two in the plane of symmetry) with the *gastrula* stage of *Sagitta*, which was regarded as the fundamental larval form (Coelomlarve). As regards Faurot's statement that the *Hexacoralla* are thus provided also with *Hauptseptum* and *Gegenseptum* (two first septa), it may be said that the *Hauptseptum* and *Gegenseptum* of the *Rugosa* are characterized not only as being the first septa lying in the plane of symmetry, but mainly by the original pinnate arrangement of the succeeding secondary septa in relation to the chief and alar septa.

Faurot insists on the fallacy of those authors who always regard the cases, which he interprets as splitting or branching of the septa, as fusion of the septa end to end, but it is doubtful whether Faurot will find any adherents to this view. On the other hand, he gives, for the stage with twelve septa, a scheme in fig. 3 demonstrating a dichotomous-like duplication of the septa, and then for some reason adduces another scheme of the same section, in fig. 4, which produces the impression that the later septa 5 and 6 become adjacent to the earlier—2 and 3—at one of their sides.

Besides, even if there is a resemblance between the first stages of development in the *Rugosa* and *Hexacoralla*, this may be due not to the origin of one group from the other, but to the origin of both groups from some remoter ancestors which possessed no skeleton, but had only soft septa.

As is seen, Faurot's views, in opposition to Jaekel's, emphasize the significance of the septa lying in the plane of symmetry. The incompatibility of the embryological data, on which Jaekel bases his views, and the palæontological data, may be due to a cœnogenetic replacement of the stages in ontogenesis.

We will now pass to the discussion of the third work, mentioned above.

Judging from his preface, Robinson's problem was to elucidate

the relationship between the *Rugosa* and *Hexacoralla*. He studied the genera of *Rugosa*, which appeared to resemble the *Hexacoralla*, in the hope, as he says, of finding in some of them an arrangement of the septa corresponding to that in the latter group. He failed, however, to find such an arrangement—all the Palæozoic *Rugosa* were found to belong to this group indisputably. The author believes that this fact strongly supports the view according to which the *Hexacoralla* have derived from the *Rugosa*, although, as he admits, he had not found a single fact which would actually contradict the opposite views. We may here recollect that the investigation conducted by Neumayr, which also established the absence of transitional forms, both amongst the Palæozoic *Rugosa* (*Tetracoralla*) and amongst the Mesozoic *Hexacoralla*, and the presence of both in different periods led Neumayr to emphasize the marked distinction (and, consequently, independence) between one group and the other. Robinson points out that, if such an independence is accepted, it should be assumed that the *Hexacoralla* have originated from ancestors lacking a skeleton, who lived in the Palæozoic era. This view was, however, already expressed by Duerden, and afterwards by others. Besides, according to Robinson, on the assumption of the independent development of the *Rugosa* and *Hexacoralla*, it would be necessary to admit a parallelism in their development which resulted in the independent appearance of analogous structures in both groups of corals. There is no reason, however, why such a view could not be accepted. Parallelism is not a rare phenomenon in allied groups, and it seems that in animals standing so low in the system, and so simply organized as the *Coelenterata*, one would be the more likely to expect such cases. The author thinks that Faurot's investigation of the development of the *Turbinolia* points to a very close relationship between the *Tetracoralla* and the *Hexacoralla*. In discussing Faurot's work above, I have pointed out that such a conclusion does not necessarily follow. Faurot himself does not arrive at a categorical conclusion in this sense, but only emphasizes the new data pointing to an affinity between the *Tetracoralla* and *Hexacoralla*. On the other hand, Robinson contradicts himself when, after having expressed the above-mentioned view on p. 153, on p. 186 he arrives at the conclusion that there can be no doubt that the *Cyathaxonidæ* do not represent the family from which one could expect a new group to originate at the beginning of the Mesozoic era. In Faurot's work, however, the comparison is actually given between the *Turbinolia* and *Cyathaxonia*.

Robinson mentions the wide distribution of the columellæ as a characteristic tendency for the Carboniferous corals. On the other hand, it is pointed out that the columella is of much more frequent occurrence in the *Hexacoralla* than in the *Tetracoralla*. These are the views set forth in the preface and in the summary following it. The next chapter is on the significance of the question regarding the primary septa, or, rather, on the first stages in the ontogenetic

development of the septa in general. The author refers to the difference in the results obtained for different *Hexacoralla*, and believes these differences can be explained either by retarded development of some septa in some groups as compared with others, or by regarding the more recent *Hexacoralla* as a polyphyletic group.

Further, there follows an investigation on the so-called Palæozoic *Hexacoralla*, in which the author arrives at the conclusion that these forms—the genera *Calostylis*, *Heterophyllia*, *Hexaphyllia*, and *Battersbya*—present genuine *Tetracoralla*, whereas *Palæacis* represents the *Tabulata*. The complex forms—*Axinura* and *Pachyphyllum*—also belong to the *Tetracoralla*.

It is quite probable that in an analogous manner the Mesozoic *Rugosa* will also prove to be non-existent. It is unknown on what grounds Frech's *Gigantostylis* (*Palæontographica*, Bd. xxxvii, Taf. xxi) is referred to the *Rugosa*. The arrangement of the septa on the lateral surface is not visible, and it is difficult to understand why Frech names the septa (fig. 11*a*) the chief, counter and alar, since in transverse section the arrangement of the septa is not bilaterally symmetrical, but distinctly asymmetrical, and probably presents an anomaly. Furthermore, the columella, on which apparently Frech chiefly bases his comparison of *Gigantostylis* and *Cyathaxonia*, is apparently not parietal. Lastly, according to Faurot's works, *Cyathaxonia* appears to differ altogether from *Gigantostylis* as regards its transverse sections.

As regards the colonial forms like *Pinacophyllum*, it is difficult to form any opinion regarding the transition which could be based on them, since the points of difference between the *Rugosa* and *Hexacoralla* are in general more marked in solitary corals than in colonial forms. In the section presented by Frech, in fig. 513, there are thirty-six septa (in one of the more distinct sections), i.e. a multiple number not only of 4, but also of 6. Besides, one can distinguish no bilateral symmetry or primary septa in any of the specimens represented in plate xxi in transverse sections (there are two of these, both in the Munich Museum, where I had occasion to examine them in the summer of 1922). Such a symmetry is present only in a schematic text-figure (p. 86) given by Frech; unfortunately, no corresponding unschematic figure is given, therefore it is impossible to judge how far the scheme represents the actual relations.

Pinacophyllum gracile, described by Voltz (specimens from Berlin: Coll. Terloff and Coll. v. Fischer) also does not show a bilateral symmetry. Voltz regards the presence of two cycles of septa as a characteristic feature for the Palæozoic corals. This, however, may also be the case in the *Hexacoralla*, in which the number of cycles of septa varies. A similar arrangement of the septa in two cycles occurs in *Coelocoema*, which, according to Voltz, presents a compact form of *Pinacophyllum*.

In the autumn of 1922 I was able to examine a modern coral, *Guynia*, at the British Museum. This coral was referred to the *Rugosa*, by Duncan, half a century ago. Duncan determined its position on the fact that in *Guynia* there are eight septa, and a columella united with one of them. I regard *Guynia* as a very original coral, even on account of its frequently attaching itself to foreign bodies only by the middle portion of the corallum. Such a method of attachment is unknown to me either in the *Rugosa* or in the *Hexacoralla*. A curious feature is also presented by the annular transverse thickenings on the exterior surface of the theca. I cannot agree with Duncan's view regarding their resemblance to the *Rugosa* in this respect. I would rather compare them with the annular thickenings on the shell of *Tentaculites*. In one specimen of *Guynia* I found, however, that six septa, and not eight, were present, and, besides, the columella is sometimes independent of the septa, as is also seen in Fig. 4 of Duncan's work. All these facts do not allow us to refer this coral to the *Rugosa*.

Haplophyllum is another coral referred to the *Rugosa* by Duncan. The number of septa (which Duncan believes to be the chief character on which the position amongst the *Rugosa* may be based) is a multiple of 4, "though a little obscured by accidental causes." It is said that the coral attaches itself by the broad base. This, however, is rather contradictory to the supposition that the coral belongs to the *Rugosa*, as well as the definition of the coral as being subcylindrical. I cannot find sufficient grounds for referring *Guynia* and *Haplophyllum* to the *Rugosa*.

In none of the post-Palæozoic corals referred to the *Rugosa* have the septa a pinnate arrangement on the lateral surface, nor is the corallum laterally attached, as is characteristic of the *Rugosa*.

The last chapter of Robinson's work bears the title: "Plasticity of the *Tetracoralla* in the Upper Palæozoic Deposits." The author states that, if the corals became less variable towards the end of the Palæozoic era, they could not have given rise to new forms. On the other hand, one may expect giant forms and monstrosities to appear before the branch declined.

The author is right in his statement that there is a peculiarity in structure in general distinguishing the Upper Palæozoic corals from the preceding forms. It is the presence of a columella in nearly all of them. The author thinks that this fact testifies to the vitality of the group, and that this peculiarity is transmitted to the Mesozoic and more recent corals.

It is doubtful whether that is the case. First of all, as is seen from the facts adduced by the author, the columella is parietal in the *Tetracoralla*, i.e. it is connected with one of the septa (this had already been pointed out before, cf. Neumayr, Stanley Smith) lying in the plane of symmetry, whereas in the *Hexacoralla* the case is different.

Furthermore, whereas the columella is present in nearly all Upper

Palæozoic corals, it is present only in about half of the Triassic genera, judging from the coral fauna of the Triassic system studied by Frech and Voltz. The facts mentioned above are more in accordance with the view that the columella of the *Tetracoralla* and the columella of the *Hexacoralla* are not quite similar structures, and have originated in these groups independently by parallel courses of development.

In my opinion, the following analogous features are presented in the development of the *Tetracoralla* and *Hexacoralla*.

Both groups appear suddenly: the former in the lower Silurian, near its boundary with the upper Silurian, the latter in the Triassic. Such sudden development is due to an origin from non-skeletal Actiniæ. The origin of both groups coincides with the period of great changes in the climate in connexion with mountain-building (Caledonian and Hercynian), when the *Hexacoralla* appeared to replace the extinct *Tetracoralla*, occupying their place in the economy of nature. In a similar manner the *Tetracoralla* probably occupied the place of the Archæocyathids and, maybe, also replaced some of the extinct Stromatoporoids.

The *Tetracoralla* and *Hexacoralla* are polyphyletic, appearing directly in several distinct stocks.

As regards the differences between these groups, the *Rugosa* typically present a conical corallum, bent on account of lateral fixation (cf. my preceding works), with the resulting characteristic pinnate arrangement of the septa on the lateral surface of the corallum, and with fossulæ; the columella ordinarily is parietal, in colonial forms the cœnenchyma is rarely developed (*Phillipsastrea*) and the separate corallites in the colonies are never so small in dimensions as in the *Hexacoralla*.

The *Hexacoralla* are distinguished by axial fixation, by a different character of the columella, which is independent of the septa. There are apparently also differences in the endotheca (tabulæ in *Rugosa*) and in the porosity of the septa (in *Hexacoralla*). The bilateral symmetry is primary in both groups of corals, but it is more marked in the *Rugosa* on account of lateral attachment.

Nepheline-bearing Lavas and Intrusive Rocks from South of the Zambezi River, with a Note on an Outcrop of Karroo Lavas in the Buzi Valley, Portuguese East Africa.

By E. O. Teale, D.Sc., F.G.S., and W. Campbell Smith, M.C., M.A., F.G.S.

(PLATE X.)

IN reviewing the tectonic features of a portion of Portuguese East Africa, south of the Zambezi, one of the present writers alone (2),[1] and also in conjunction with Capt. R. C. Wilson (1),

[1] Figures in parentheses refer to bibliography at the end of the paper.

advanced the view that the surface topography had to some extent been affected by the same movements which were associated farther north with the Rift Zone period of Eastern Africa. This opinion was arrived at from the consideration of the physiography, the observation of definite faulting in places, especially in western Sheringoma on an extension of the Nyasa-Shire line, and also of volcanic occurrences elsewhere in significant positions.

Later, petrological examination of some of the intrusive and effusive rocks from these regions showed that both calcic and alkaline types were represented, but the opportunity was not available for making the desirable comparisons with the typical alkaline rocks of Eastern Africa until recently, when one of the present writers undertook the task.

Since Teale and Wilson made their traverse of this region in 1913, F. P. Mennell (3) has been over some of the ground and has published some preliminary notes, in which he points out that the volcanic rocks of the Lupata Gorge are overlain by sandstones which he regards as Cretaceous, and he considers that the volcanics, which he recognizes as including rhyolites and nepheline-bearing lavas, cannot be younger than Lower Cretaceous. They are separated from the Karroo lavas, a few miles above the gorge, by sandstones. Teale and Wilson expressed no opinion concerning the age of the Lupata volcanics, for though they recognized that they were older than the sediments of Sena to the east they had no fossil-evidence of Cretaceous rocks nearer than the lower beds of Sheringoma, which lie to the east of the Urema faults. It is of some interest, therefore, that the petrological examination of the specimens they collected of the Lupata volcanics showed that these specimens resemble types of the Kapitian phonolites of Kenya Colony which Professor J. W. Gregory regards as of Upper Cretaceous age.

The three specimens collected at Lupata Gorge (Nos. 26, 27, and 28) are porphyritic (dopatic) rocks with pale flesh-coloured phenocrysts of nepheline and anorthoclase in a dull-purple groundmass. The phenocrysts are sometimes 1 cm. long. There are a few small phenocrysts of aegirine-augite and occasional patches of partly resorbed brown hornblende. The groundmass is very fine-grained. In Nos. 26 and 28 it consists of brown soda-amphibole (? katoforite), with less abundant cossyrite and aegirine evenly distributed between very thin laths of orthoclase with perhaps a little nepheline and an isotropic base (? sodalite). The felspars are without any directional arrangement. In the third specimen (No. 27) there is very evident flow-structure, minute idiomorphic nephelines are abundant, and katoforite was not observed, but all the nepheline and the interstitial base has been altered to a turbid reddish aggregate and the amphiboles are probably altered too.

The two fresh rocks (Nos. 26 and 28) devoid of flow-structure correspond almost exactly to the olivine-free types of Kapitian phonolite described by Miss Neilson (4), whose description is based

on specimens collected by Professor Gregory in Kenya Colony in 1919. Mr. Mennell's observation that the Lupata volcanics are overlain by Cretaceous sediments, and the close similarity between the specimens from the Lupata Gorge just described and the Kapitian phonolites, seem to afford very striking confirmation of Professor Gregory's view that the latter are of Cretaceous age.

It is interesting to note that there is a certain degree of similarity between the groundmass in No. 27, described above, and the aegirine-trachyte described by Holmes (5) from north of Sokoto Hill in the Mozambique district. Dr. Holmes' specimen is much altered, but some of the altered material was undoubtedly idiomorphic nepheline, and the rock should be classed as a phonolite. Dr. Holmes regarded it, and the other soda-rich volcanics from that area, as Tertiary, but the rocks were not found *in situ*, and its age cannot be accepted as settled. Its comparison with the phonolitic trachyte of L. Baringo, described by Prior (6), does not appear to us to be very close.

The other soda-rich rocks described in this paper come from a region south of the Zambezi, where outcrops are found at intervals as far south as Bunga Hill on the western edge of the Urema Sunkland, 150 miles south-south-east of the Lupata Gorge (Map, Fig. 1). Unlike the Lupata volcanics, which appear to be true lavas, these rocks from south of the river form isolated conical hills or groups of hills which suggest that they are "necks" protruded through the older rocks around them. In the western area the surrounding rocks are either the gneiss, as at Chinje, or the Karroo lavas, which here form a belt following closely the eastern margin of the crystalline rocks. Two isolated occurrences of olivine-nephelinite farther east are intruded through later rocks, that of Baramwana cutting the Sena (? Cretaceous) Sandstones, and that of Inkweyri invading beds of Eocene age. In the extreme south the phonolites and nephelinites of Panda and Bunga Hills are associated with the marginal fractures of the Urema Sunkland, which are probably the latest tectonic lines and are probably post-Miocene.

The specimens collected include phonolites, trachytoid phonolites rich in sodalite, nephelinites, and olivine-nephelinites (nepheline-basalts). The results of their detailed petrological examination shows that there exist very close resemblances between these Portuguese East African rocks and many of the lavas of Kenya Colony, eastern Uganda, and Tanganyika Territory, and it has been possible to some extent to correlate them with lavas belonging to various members of the succession established by Professor Gregory (7) in Kenya Colony.

The *phonolites* from the area west of Sena are compact aphanitic rocks, in colour sage-green mottled with chocolate, and with a slightly resinous lustre. All contain abundant microphenocrysts of nepheline, and a few of aegirine, aegirine-augite, or soda-amphiboles. Some of them carry rather rare phenocrysts of anorthoclase.

In the specimens from Kalangamunzi (Nos. 48 and 49) the micro-

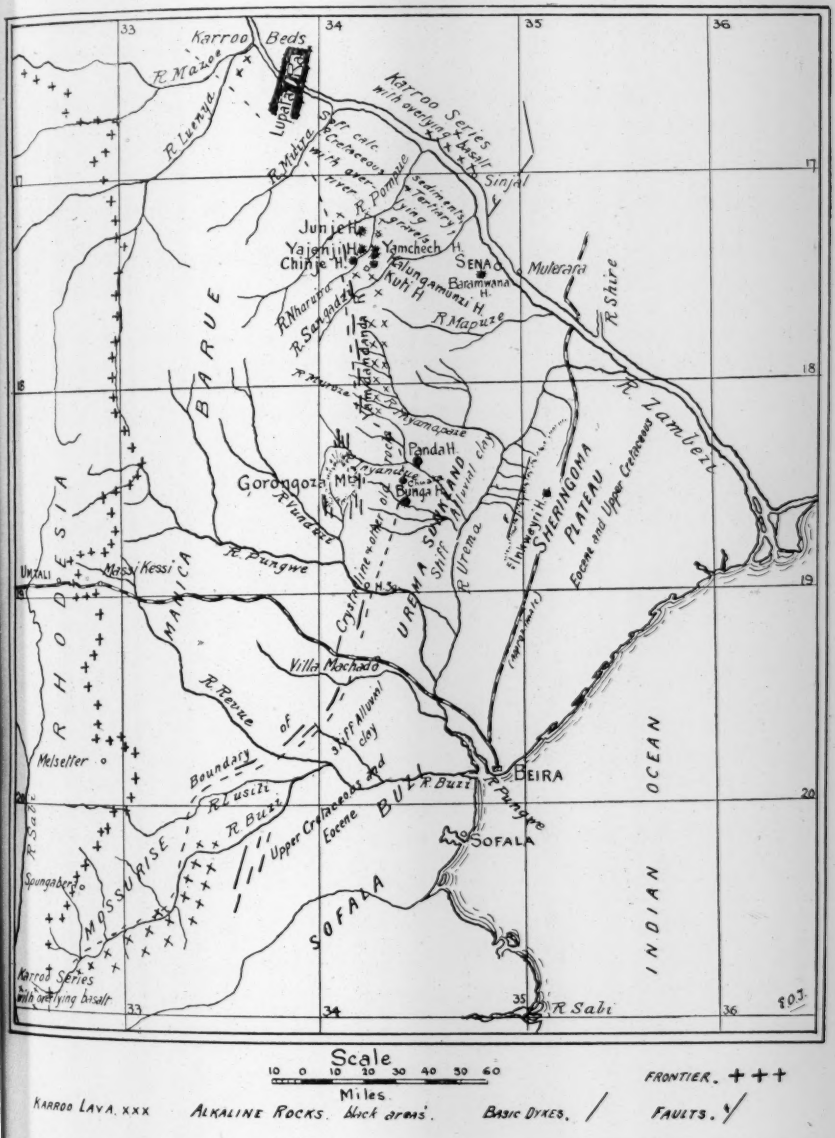


FIG. 1.—Map of Portuguese East Africa between the Zambezi and Sabi Rivers, showing occurrence of Karroo and later nepheline-bearing lavas.

phenocrysts are abundant nepheline and rare aegirine, and the groundmass consists of very thin laths of orthoclase and minute nephelines (0·02 mm. in diameter), with some isotropic base (? sodalite) and many dark patches, due to the aggregation round the nepheline micro-phenocrysts of aegirine and soda-amphiboles.

No. 46 from Chinje Hill is quite similar, but contains a few phenocrysts of anorthoclase, rather less nepheline, and more micro-phenocrysts of aegirine, which project into what appear to be minute vesicles filled with analcite or sodalite. This rock is less altered than those from Kalangamunzi. Some of the dark patches have the characters of the riebeckite- or arfvedsonite-like mineral mentioned by Prior (8).

A phonolite (No. 44) from Yajenje belongs to the same type as that last described. The phenocrysts of anorthoclase (1–3 mm. in length) are fairly numerous, but are altered to radiating aggregates of natrolite. Microphenocrysts of aegirine were not observed, but there are a few rounded partly resorbed crystals of katoforite and cossyrite, and rare microphenocrysts of aegirine-augite. In the groundmass there is the same tendency for the abundant aegirine and the soda-amphiboles to gather round the nepheline microphenocrysts, but in this rock the dark patches are aggregates of minute spindle-shaped or subhedral prismatic crystals rather than the spongy micropoecilitic plates seen in the rocks just described. The development of zeolites in this rock is rather interesting. Not only are the anorthoclase phenocrysts altered, but the whole groundmass, which appears almost isotropic where unaltered, is spotted with birefringent areas, often circular in outline, showing a black cross between crossed nicols and presumably spherulitic. They sometimes show no visible nuclei, but more often they are seen to radiate from felspar phenocrysts, and the zeolite which replaces the anorthoclase can be seen extending beyond the felspar into the surrounding groundmass, and apparently affecting the felspar and nepheline as well as the interstitial isotropic base. The zeolite mineral has straight extinction, positive elongation, and a refractive index near and slightly less than 1·487. These characters agree with those of natrolite (Pl. X, Figs. 1 and 2). A similar spherulitic growth has been described by Dr. Marshall (9) in the groundmass of a tinguaite from near Dunedin, New Zealand.

The two other specimens from Yajenje Hill (Nos. 42 and 43) are trachytoid phonolites containing a few phenocrysts of felspar (? anorthoclase) in a groundmass of laths of orthoclase, small idiomorphic nepheline, with aegirine and cossyrite, and some interstitial isotropic base. The felspar is dominant over nepheline and the texture is clearly trachytic. Zeolitization has again affected the groundmass.

The phonolite (Nos. 106 and 109) from Chuata Mt. is rather different from those just described, and appears to be richer in nepheline. It is a porphyritic (dopatic) rock with whitish centi-

metre-long anorthoclase and red-stained nephelines (2–3 mm. across) in an aphanitic chocolate-mottled slate-grey groundmass. Microphenocrysts consist of rare aegirine-augite, a few aggregates of small crystals of katoforite and some patches of small crystals of aegirine possibly pseudomorphous after hornblende. Sphene and an iron oxide appear as rare accessories. The groundmass consists almost entirely of small idiomorphic nephelines with abundant microliths of aegirine and a colourless interstitial base which consists, in part at least, of orthoclase. Zeolitization has attacked the nepheline and the interstitial base in patches.

The katoforite in this rock is rather well-crystallized and gave pleochroism: α pale yellowish-green, β pink-lilac, γ pale-green.[1] $c : \gamma = 35°$.

The other two specimens from Chuata Mt. (Nos. 107 and 108) are described tentatively as *trachytoid phonolites*, but their striking characteristic is a remarkable richness in an isotropic base which from chemical and optical characters appears to be partly *sodalite*. The percentage of chlorine in the rock was determined by Mr. E. D. Mountain, of the Mineral Department, British Museum, who found 0·11 per cent, corresponding to about 1·4 per cent of sodalite, or about half the amount found by MacGregor and Ennos (10) in the phonolite of Traprain Law. The rock is porphyritic (perpatic), with very rare phenocrysts of nepheline and anorthoclase, and a very few small black blades in a compact aphanitic groundmass of dull walnut-brown mottled with resinous lustrous patches. The black blades visible in the hand-specimen appear to be partly brown hornblende and partly augite (? aegirine-augite). The latter mineral occurs in small idiomorphic crystals (0·16 mm. to 1·6 mm. thick), pale green, feebly pleochroic, and often with a colourless central core: $c : \alpha = 34°$ to 39°. Sphene and magnetite are rather abundant in very small crystals, with occasional larger crystals of the former. The groundmass has very marked trachytic texture, and consists mainly of very thin laths of orthoclase with much interstitial colourless isotropic base, including some minute idiomorphic nephelines. Scattered through the whole groundmass are abundant minute crystals of aegirine, some aegirine-augite, a little cossyrite, magnetite, and accessory sphene and apatite. Zeolitization has given rise to reddish turbid patches in the groundmass. Very striking are small glomeroporphyritic patches of augite which often have a core of brown hornblende surrounded by magnetite grains; the larger sphenes are also associated with these patches, which seem to be related directly to the resorption of the hornblende.

There is no doubt that the phonolites just described are closely related to some of the volcanics of Kenya Colony, but it is difficult at present to refer them to particular types which can be recognized

[1] Names of colours used are taken from "Color Standards and Color Nomenclature". By R. Ridgway, Washington, 1912.

as belonging definitely to one or other of the series in Gregory's succession. The rocks of Kalangamunzi, Chinje, and Yajenje Hills, all characterized by the presence of aegirine and soda-amphiboles, with a marked tendency for these minerals to gather round the nephelines, are possibly comparable to some of the phonolites (Kenya type) of Miss Neilson, and No. 46 from Chinje Hill is rather similar to the phonolite of Mt. Höhnel (Kenya type of Prior) belonging to the Doinyan series. If these comparisons are sound, the phonolites of the Sena area are probably pre-Nyasan. At present not enough is known of the position of this type in Kenya Colony for us to regard it as necessarily restricted to the Doinyan series, especially as some of the lavas (Nos. 325, 327), classed by Miss Neilson with the Kenya type, are shown by Gregory, in a figure of a section near Kisumu, as in the Kapitian series (11).

If the correlation of the phonolites with those of Kenya Colony is vague, the case is quite otherwise with the nephelinites, for here one is on more certain ground. The nephelinites can be matched exactly with rocks on the shore of Victoria Nyanza which are known to be definitely post-Miocene in age and with other rocks erupted from the sub-recent volcanoes of Tanganyika Territory.

The *nephelinites* may be referred to three types. The first is represented by three specimens from Panda Hill. They are porphyritic (dopatic) and show rather abundant small brick-red phenocrysts of nepheline evenly distributed in an aphanitic greenish-black groundmass. These are all slightly vesicular. One of them (No. 114) contains abundant very small phenocrysts of aegirine-augite and microphenocrysts of magnetite and apatite evenly distributed through the rock. The groundmass consists of small (0·03 mm.) idiomorphic crystals and rounded patches of nepheline and some interstitial base of lower refractive index, all crowded with minute microliths of aegirine and aegirine-augite. Small interstitial patches of lemon-yellow or bright-green glass are abundant. Throughout the groundmass in two specimens (Nos. 111 and 113) there are abundant rectangular patches of clear felspar (? orthoclase) which enclose in poecilitic fashion the nepheline and microliths of aegirine, and have evidently developed later than the main fabric of the groundmass.

The second and third types are both characterized by abundant augite, which occurs in crystals of three generations, and they all carry biotite and magnetite as microphenocrysts. Nepheline is confined to the groundmass.

The augite is very pale pinkish-buff, almost colourless, in thin section. $c : \gamma = 46°$. The biotite is biaxial with 2 E about 50°. Plane of the O.A. parallel to the plane of symmetry. Pleochroism: α maize-yellow, β chestnut-brown, γ orange-rufous. A frequent face-colour is bright gamboge-yellow.

The distinction between these two types is found in the nature of the groundmass. In one type, represented by aphanitic slate-grey

rocks from Kuti Hill (No. 51) and Bunga Hill (No. 105), the groundmass consists of abundant very minute nepheline crystals in a cloud of microliths of augite (0·006 mm. thick), with very minute grains of magnetite and small amounts of an interstitial base, possibly nepheline, but partly of lower refractive index. The specimen from Bunga Hill (No. 105) is traversed by numerous roughly parallel narrow channels filled with felspar in singly twinned plates. Only in one case was an appearance of multiple twinning observed.

In a third type (No. 50), from Yamchech Hill, the groundmass is made up of large allotriomorphic plates of nepheline and singly twinned felspar through which a few plates of biotite and crowds of augite microliths and minute cubes of magnetite are distributed. The nepheline and felspar are present in approximately equal amount. The nepheline encloses about five times as much of the augite microliths as the felspar does, so that the felspar plates show up as lighter areas in thin section (Pl. X, Fig. 3). This rock in the hand-specimen is porphyritic (perpatic), with small black blades of augite in a compact aphanitic blackish groundmass.

No. 104 from the top of Bunga Hill is quite similar in the main to the rock just described, but the groundmass contains many patches in which the augite microliths are associated with very thin, often curved, felspar laths in an altered groundmass which may have been in part glassy. These patches include a few very small flakes of biotite which is otherwise absent in this rock. Another distinction from the rock described above is the presence round the augite phenocrysts of an outer shell with higher extinction, $c : \gamma = 52°$, and faintly pleochroic in shades of pale-drab.

The felspar of the allotriomorphic plates seen in the groundmass of the two nephelinites last described is no doubt identical with the mineral described as sanidine in the "nepheline-basalt" of Katzenbuckel (12) and in many nephelinites from East Africa (13), but no satisfactory measurements of extinction-angles or other optical characters have been obtained from the Portuguese East African rocks. Mr. E. D. Mountain determined the alkalies in the nephelinite (No. 50) of Yamchech Hill and found Na_2O 3·42 per cent, K_2O 1·99 per cent. If all the soda were present as nepheline, the ratio of nepheline to orthoclase in the rock would be about 3 : 1. Measurements made on a thin-section show that these two minerals are present in almost equal proportions; so it is probable that some of the soda is present as albite, and the felspar is either soda-orthoclase or anorthoclase rich in potash.

We have been able to study these nephelinites side by side with the nephelinites and "nepheline-basalts", described by Oswald (14) in 1914, from the Gwasi Plateau, east of Lake Victoria Nyanza. The olivine crystals of his "nepheline-basalts" are of very sporadic occurrence, and may be xenocrysts. None were observed in three nephelinites from the same area described and analysed by

Goldschlag in 1912 (15). Neither of these two authors record biotite in the Gwasi Plateau rocks, but in every other respect the nephelinites described above, and particularly those of the third type from Bunga Hill and Yamchech Hill, are very nearly identical with the rocks described by Oswald. These nephelinites of the Gwasi Plateau overlie sediments of which the lower beds are certainly Miocene and the uppermost beds may be possibly Pliocene.

Rather similar nephelinites have been described by Prior from 7,000 feet on Mount Elgon, but at higher elevations (8,000 feet) the rocks, though still belonging to the same type, differ in containing rather abundant melilite and perofskite. Gregory regards these Elgon lavas as younger than those of the Gwasi Plateau and possibly late Pliocene in age.

In Tanganyika Territory nephelinites, associated with tephrite, leucite-basanite, and melilite-basalt, have been recorded from Ngongoro, Kilima Njaro, the shores of Lake Natron, Meru, and Essimingor, and, still further south, from Gurui, Massai Steppe, and Ufiomi. According to Gregory they are still being erupted from the active craters of Kirenga and Oldonyo l'Engai.

Thus it appears that in Kenya Colony the nephelinites are restricted to Gregory's Naivashan series and are definitely post-Miocene in age. In Tanganyika Territory they are everywhere associated with the more recent of the large volcanoes. The nephelinites of Portuguese East Africa are exactly the same in general characters as those of Kenya Colony, and it seems quite justifiable to assume a post-Miocene age for these too.

The *olivine-nephelinites* (nepheline-basalts) were found forming two isolated intrusions, one in the Inkweyri Hills, the other at Baramwana Hill, near Sena. No. 122 from the Inkweyri Hills is a compact aphanitic blackish slate-coloured rock with very occasional rounded crystals of olivine, 1–2 mm. long. The groundmass is holocrystalline, even-grained, grain-size about 0·15 mm., with panidiomorphic-granular texture. It consists of colourless olivine, very pale augite-microliths, 0·03 mm. thick, and allotriomorphic nepheline, with rather abundant magnetite and perofskite in good crystals, 0·04 mm. across. In addition there are numerous poecilitic plates, up to 0·05 mm. in diameter, of orange biotite similar to that observed in the nephelinites (Pl. X, Fig. 4).

No. 29 from Baramwana Hill is a holocrystalline-porphyritic type of the above, in which the olivine all occurs as colourless crystals, varying from well-developed phenocrysts 0·8 mm. long to minute rounded crystals 0·07 mm. in diameter. The groundmass consists of microliths of augite, 0·006 mm. thick, and interstitial patches of nepheline, with a little biotite, and abundant magnetite and perofskite crystals varying in size from 0·03 to 0·009 mm. across. There are some included patches of nepheline which appear to be xenocrysts.

The only definite evidence of the age of these two rocks shows,

as has been mentioned above (p. 228), that the Baramwana intrusion is later than the Sena Sandstones, and that the one at Inkweyri penetrates beds of Eocene age. No rocks of quite the same type have been recorded elsewhere in East Africa, but there can be no doubt that their relation to the nephelinites is a close one, and this relationship is rather confirmed and emphasized by the abundance of perofskite, which is so characteristic of the melilite-bearing nephelinites of Mount Elgon described by Prior (16). Their rather unusual characters may be significant, for they occur many miles to the east of the outcrops of the phonolites and nephelinites described above and apparently east of the eastern boundary of the "rift".

It seems clear that this group of nepheline-bearing rocks represents a succession of igneous intrusions ranging from Cretaceous probably into post-Miocene times and forming a southward extension of the great soda-rich province of Kenya Colony and Tanganyika Territory and associated with a set of tectonic lines related to those of the "Rift Valley". It is interesting to note a gradual waning of igneous activity and an apparent falling off in the supply of material as this series of rocks is traced southward, until, south of the Zambezi, no longer does one find extensive flows of lava, but only a few small intrusions occurring sporadically along the lines of faulting.

The soda-rich rocks of Mozambique described by Dr. Holmes, and referred to above, are farther north and occur on a more eastern fracture zone much nearer the existing coast-line, but they are associated undoubtedly with the same succession of crustal adjustments of Eastern Africa ranging from late Karroo through Cretaceous to at least mid-Tertiary times.

It is important that the outcrops of the nepheline-bearing rocks shall not be confused with those of the Karroo Lavas, with which they are closely associated in the northern part of the area. The Karroo Lavas have a very considerable extension in the country, and outcrop at widely separated areas on both sides of the Zambezi River. On the northern side they overlie Upper Karroo beds at Sinjal; Mennell (3) has described their occurrence on the southern bank between Tete and the Lupata Gorge, and again farther south, where he finds them forming a bed 7 or 8 miles across. As indicated in the map (Fig. 1), they can be traced in a southerly direction at frequent intervals for well over 100 miles, following closely the eastern margin of the crystalline rocks, but usually separated from them by a narrow zone of underlying grits and sandstones of presumably Upper Karroo age.

As indicated by Mennell, this belt of volcanics terminates north of the Gorongoza mountains, and there is then a long gap extending southwards where alluvium of the lowlands is in direct contact with the crystalline rocks and no sediments or volcanics are visible, but the latter re-appear in Mossurise in the Middle Buzi and Morungwezi

valleys. The underlying Karroo rocks also outcrop near the frontier, and both extend westerly to the Sabi valley in Rhodesia. The southern lavas can thus be traced continuously for about 100 miles. In both the Zambezi and Mossurise regions the original area of the Karroo basalt must have been very great, for the existing outcrop only represents more or less the margin of extensive flows, now buried for the most part beneath Cretaceous and Tertiary sediments. This outcrop is regarded as lying on or near the margin of an important fracture zone bordering foundered blocks of Karroo sediment resting against the "crystalline schists" and other old rocks. Renewed adjustments with the formation of fresh fractures took place at successive periods in Cretaceous and Tertiary times associated with the injection, both along old and newer lines, of soda-rich lavas which, however, as far as at present known, were confined to the northern areas in the country. A noteworthy feature, however, of all the Karroo basalts in this region is their highly amygdaloidal character and the prevalence of soda-bearing zeolites in the amygdales.

Attention has been drawn by Mennell to the remarkably intricate injection of igneous material into the Karroo rocks in the Maringwe district. This is a very general feature throughout the margin of the sediments and extends into the crystalline rocks also, often indicating a marked shatter zone. Such is particularly the case immediately north of the Gorongoza Mountains.

The whole of the petrological work of this paper has been carried out in the Mineral Department of the British Museum. W indebted to Dr. Herbert H. Thomas for his kindness in arranging for the photomicrographs to be prepared in the laboratory of H.M. Geological Survey.

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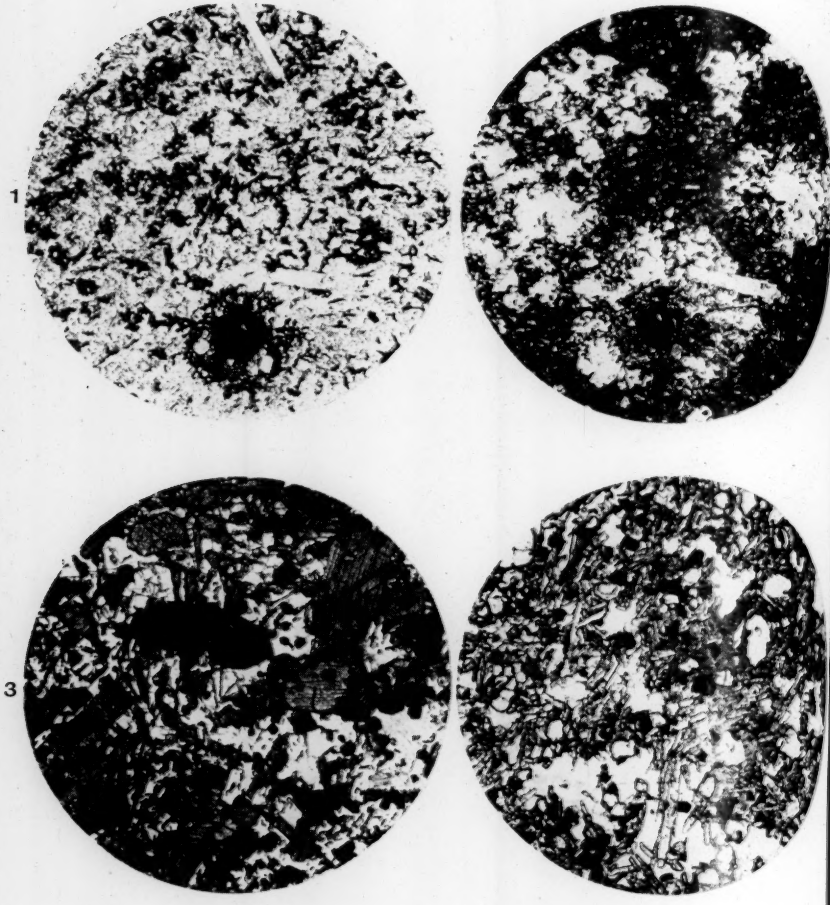

PHOTOMICROGRAPHS OF NEPHELINE-BEARING LAVAS.

To face p. 237.

(11) J. W. Gregory, loc. cit., fig. 16, p. 124.
(12) W. Freudenberg, "Geologie und Petrographie des Katzenbuckels im Odenwald": *Mitt. Badisch. Geol. Landesanst.*, vol. v, 1907, p. 216.
(13) H. Rosenbusch, *Mikroskopische Physiographie der Massigen Gesteine*, 1907, vol. ii, p. 1434.
(14) F. Oswald, "The Miocene of the Victoria Nyanza and the Geology of the Country between the Lake and the Kisii Highlands": *Q.J.G.S.*, vol. lxx, 1914, pp. 140–3.
(15) M. Goldschlag, "Beiträge zur Kenntniss der Geologie und Petrographie Ostafrikas": *Centralbl. f. Min.*, 1912, pp. 593–5.
(16) G. T. Prior, loc. cit., p. 250.

EXPLANATION OF PLATE X.

FIG.

1.—*Phonolite*; Yajenje Hill. Specimen No. 44. Magnification 36 diameters. Photograph taken in ordinary light (p. 230).

2.—The same field photographed between crossed nicols to show up the zeolitic patches. Magnification 32 diameters (p. 230).

3.—*Nephelinite*; Yamchech Hill. Specimen No. 50. Magnification 40. The light areas are plates of felspar. The black patch near the centre is mainly due to a basal section of biotite (p. 233).

4.—*Olivine-nephelinite* (Nepheline-basalt); Inkweyri Hills. Specimen No. 122. Magnification 40. Two poecilitic plates of biotite are seen near the right-centre. Cubes of perofskite have photographed dead-black and are indistinguishable in the plate from magnetite. Both the olivine and nepheline appear quite white (p 234).

REVIEWS.

1. Uganda Protectorate. Ann. Rept. Geol. Depart. for Year ended 31st March, 1920. pp. 88, 4 maps, 3 sketches. 1921.
2. Southern Rhodesia. Rept. of the Director, Geol. Survey for the Year 1921. pp. 4.

IN the first report Mr. E. J. Wayland and Mr. W. C. Simmons (Government and Assistant Geologist respectively) make a most important contribution to the Geology of Uganda. The rocks of the Protectorate are divided into eight "age-groups"; the first of these, the basal Archæan complex (the constitution of which is not discussed), is locally covered by an important group of "clay-like rocks", the Argillite Series (Group 2). These beds cover a large area and have in one place yielded the genera *Gangamopteris* and *Psygmophyllum*, although the determinations are not certain (footnote, p. 66). The relations of the Argillite Series to the Karagwe Series are not touched on—presumably the two are in part the same, but the present writer cannot avoid the suspicion that the former wil. be found to include sediments dating much farther back than the Permo-Carboniferous. Passing over the third group (of "Post-Argillite Intrusives"), we find the remaining five groups consist of sedimentary (including lateritic) and volcanic rocks, dating from the Miocene onwards. The oldest of these (Group 4), the Karamoja Beds, earlier than the Mount Elgon Volcanic Series (Group 5), provide fresh evidence of the great extent of the Lacustrine Phase which characterized so considerable a part of Equatorial Africa from Miocene times on.

The greatest altitude of the Karamoja deposits lies "between 4,000 and 4,700 feet above M.S.L."; Lake Victoria then embraced Lakes Kioga and Salisbury and spread over the site whereon now Mount Elgon stands. The northern drainage of this great sheet of water one hopes will be elucidated in subsequent publications, but a study of the latest topographical maps suggests that one such discharge may have been in an easterly direction, across the Suk Mountains, taking the course of what is now the Turkwel Gorge.

The Mount Elgon Volcanic Series, mapped as far north as Mount Moroto, followed after an interval, and it is interesting to note that Mount Elgon is not considered to be a volcano of the "typical Vesuvian variety", and the probability exists that this volcanic series is rather the result of fissure eruptions of which Elgon itself may or may not be the centre. Apparently, this volcano is related to Mount Marsabit, on the eastern side of the Koroli desert, formed by the piling up of a huge but relatively low cone by successive out-pourings from a single vent or a group of closely adjacent vents. In such a report, where so much new ground has been broken, many points of interest must be passed over, and the tectonics of the Protectorate referred to but briefly. The suggestion (par. 58) that the deposition of the Argillite Series took place in a depression produced by block-faulting is noteworthy, as is the "fold of enormous dimensions" (par. 59) postulated as extending from

the Congo into Uganda and having a main axis along the Western Rift. More evidence for these suggestions is desirable. The writer entirely agrees with Mr. Wayland on the importance of the North-West-South-East trend lines north of Lake Victoria (par. 147).

The report includes, amongst other matters, notes on Earthquakes, "Native Metal Lore," a list of "Minerals known to occur in Uganda," with fuller notes on those of economic importance. Mention is also made of the hot springs and water supply. Altogether the officers of the Survey are to be congratulated on this publication, to which obviously much care has been given.

(2) This brief report records the continuation of the recent work of the Rhodesian Survey in the Bubi and Lomagundi districts; the former north of Bulawayo, the latter (Sinoia area) in Northern Mashonaland. The Bubi district is noteworthy as containing some of the oldest rocks in Southern Rhodesia: a basal "greenstone group" of volcanic origin, overlain by a sedimentary group, the Ndutjana Series.

The relation between these and the intrusive granite is such as would result from the downward sagging of the former upon the surface of the latter. This supports the "Theory of the Geological Structure" put forward by Maufe in 1913 (Bulletin No. 2).

Of the Lomagundi District but little additional information is given. The Provisional Geological Map of Southern Rhodesia is now completed.

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THE WEGENER FREQUENCY CURVE.

SIR,—The idea that there is one level of the ocean bottoms and another of the continents is so old that I am sure Wegener himself lays no claim to its discovery. It is diagrammatically displayed in almost every atlas of the world, and its general truth appears highly probable. What is perhaps not so widely known is that the evidence on which the idea is based is not as yet complete enough to enable it to be treated as a rigidly established fact. It was no doubt this deficiency in the evidence that tempted Wegener to treat the question statistically, and so get rid of any possible imputation that the personal factor entered into the interpretation of the evidence. Hence has arisen the "Wegener Frequency Curve", a term to which there can be no objection provided it is understood that it is the curve and not the idea which is Wegener's; and provided also it is remembered that the idea is not yet an established fact, but merely an interpretation of existing evidence, which is receiving confirmation with every line of soundings flung across the ocean depths.

The conception that the crust of the earth approximates to two main levels has thus come to be widely accepted as a sort of working